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Impact of crop-yield technology on US crop production

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IMPACT OF CROP-YIELD TECHNOLOGY

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CHAPTER I

INTRODUCTION

Today more than half of the world's population suffers from varying degrees of hunger and malnutrition (1, p. 160). World food production is rising but not rapid enough. During the first half of this century world population increased by 900 million people, estimates for the second half put population increase at 3.8 billion people (2, p. 23). Considering that world population just reached the 2.5 billion mark in 1950 it means that population increase between the years 1950 and 2000 is expected to surpass population growth of all past centuries combined. World food production has risen too. During the last decade annual increase in world food production exceeded population growth by .4 percent, a favorable but narrow margin. To provide adequate food for the world by 1980 the annual rate of increase in food production would have to exceed population growth by 2.25 percent (1, p. 148). Measured by this criterion the current rate of increase in world food production is inadequate and would need to be about five times as great.

Provided sufficient resources are allocated to food production and food technology it is difficult to see why a great part of the world population should be undernourished in the future. Someday synthetic food may eliminate the world food problem. Today and in the near future the problem can be alleviated if current production technology is shared more equally among nations. Aside from availability of resources and technical knowledge the economics of production, more specifically the efficiency of the economic incentive system, may well be the most importan prerequisite for success. Farmers of modern capitalistic countries operating under private enterprise systems have outproduced farmers of communist economies. On the North American continent a capitalistic incentive system in combination with technical know-how and resource availability has allowed food production to surpass requirements.

The problem of U.S. agriculture is not shortage but overproduction. Carry-over stocks of wheat and feed grains exceed desirable levels. During the last decade U.S. wheat consumption and export requirements averaged about one billion bushels per year. It has been estimated that 40 to 50 percent of annual wheat requirements represent a desirable level of wheat carry over (3, p. 141). By this standard almost one billion bushels of the 1961 wheat carry-over was surplus wheat, the equivalent of one year's requirements. A desirable level of feed grain carry-over was estimated at one quarter of annual consumption and export needs. About 30 million tons would have met this requirement but carry-over stocks in 1961 exceeded 80 million tons (4, p. 6). Hence about 50 million tons or two-thirds of the 1961 feed grain carry-over could be considered surplus (3, p. 140).

A rapid rise in crop yield reduced the effectiveness of federal programs aimed at surplus reduction. Wheat acreage allotments have been in effect each year since 1954 and under this program U.S. wheat acreage has been reduced by about 30 percent. Over the same period U.S. wheat yields per acre rose sharply, reached a peak in 1958 and have remained approximately 50 percent above the 1953 yield level (5, p. 1). Consequently U.S. wheat production was somewhat higher during recent years, despite significant acreage reductions. Yields of feed grains rose sharply too. In 1953 U.S. feed grain yield was .88 tons per acre, by 1961 it reached an all time high of 1.28 tons per acre. Compared to 1953, feed grain acreage in 1961 was down 15 percent but production was up 25 percent. Gains in yield per acre more than compensated for acreage reduction effects (4, p. 1).

The question arises, what gains in future food and feed grain production can be expected in the U.S.? Will U.S. food supplies be as abundant in the future as in the past? At the turn of the century U.S. population had just passed the 15 million mark, by 1950 it exceeded 150 millions. This represents a 900% increase compared to a 60% gain in world population (6, p. 14). During the second half of this century U.S. population is expected to almost double again, reaching 285 millions by the year 2000 (2, p. 23) whereas world population is expected to more than double. Considering the present level of U.S. food production and U.S. population growth it appears the United States is in a better position to meet her food requirements than the rest of the world. Assuming for the moment that there will be no shortage will there be a chronic surplus? If so what adjustment possibilities exist and how can the goal of balanced production be achieved most efficiently? To answer these questions detailed analysis of past production trends becomes important.

Johnson and Gustavson analyzed grain yields in relation to American food supply. Their investigation was based on multiple regression analysi of relative changes in crop yields between two time periods. Two sets of cross-sectional data were analyzed, one set related to 21 eastern states, the other to 18 western states. Johnson and Gustavson estimated that a 40 percent increase in grain yields, necessary by 1980, would require 8.2 million tons of plant nutrients (7, p. 116). Considering that U.S. farmers applied 7.8 million tons of plant nutrients in the 1960-61 crop year already, (8, p. 22) it would certainly appear feasible to apply 8.2 million tons of plant nutrients by 1980. However, the authors states, "We cannot assume that the increased fertilizer is the sole cause of the increase in yields. The higher rate of fertilizer use may be a necessary condition, but it is undoubtedly not a sufficient condition" (7, p. 117). Johnson and Gustavson did not quantify other inputs needed to achieve a 40 percent yield increase by 1980. They attributed two-thirds of the 1957-60 increase in wheat yields and one-sixth of the 1957-60 increase in corn yields to better weather conditions (7, pp. 136, 137). Their 1975 projections of corn yields ranged from 53 to 82 bushels per acre (7, p. 143). Corresponding estimates of the Paley Commission, made ten years earlier, ranged from 55 to 80 bushels per acre (7, p. 144). Johnson and Gustavson's analysis did not narrow the range of these earlier estimates.

In recognition of the need of better crop yield projections the Center of Agricultural and Economic Adjustment sponsored several studies by Thompson (9, 10). Using state data he regressed corn yields on monthly weather data and a time trend variable. Thompson concluded that better than average weather conditions accounted for most of the corn added to storage after 1957 (9, p. vii). Extrapolating Thompson's time trends puts the 1975 average yield of corn in the Corn Belt at 73 bushels per acre.[1]

[1]The 1960 ratios of corn acreages among Corn Belt states were assumed to remain constant.

This extrapolated corn yield is based on Thompson's assumption that corn yield trends due to technology are linear. Thompson did not specify what production inputs are needed to increase corn yields at a constant rate over time, nor did he attempt to determine what economic factors would give farmers the incentive to raise crop yields in the future.

Nerlove endeavored to estimate the farmers' production response to price. In his recent book The Dynamics of Supply, he concentrated his econometric analysis on "the role which farmers' expectations of future prices play in shaping their decisions as to how many acres to devote to each crop" (11, p. 21). As earlier writers he approximated planned crop output by acreage (11, p. 66). According to Nerlove the ideal case where planned output can be computed by inputs committed to its production is difficult to approximate for several reasons:

> "(1) Different crops are not independent of one another in production.[1]
> (2) Inputs are not committed completely at the beginning of each production period.[2]
> (3) The production functions are not known and even if they were known at a point in time they might be constantly changing over time.
> And finally,
> (4) with the exception of land, available data do not permit the allocation of factors of production among different outputs which are produced in the agricultural sector. Approximation of planned output in a production period by acreage is the only possible approximation within the limits prescribed by existing knowledge, the conditions of production, and the available data" (11, p. 66, 67).

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[1]This is evident from the fact that crops are commonly rotated. See Chapter V.

[2]Not even land is fully committed at the beginning of the production period because of the possibility of abandoning planted acreage before harvest.

Nerlove's conclusion represents a challenge. During the last two decades cropland acreage declined from 368 million acres in 1940 to 355 million acres in 1960, a decline of 13 million acres or four index points. Over the same period of years the index of crop output rose from 78 to 108, a rise of 30 points and the index of crop production per acre advanced from 76 to 109 points, a rise of 33 points (12, pp. 12, 19, 20). Obviously, advance in crop yield technology and not acreage was responsible for this increase in output. A method of analysis which ignores change in crop yield technology may be suitable for study of the dynamics of supply of an earlier time period when crop yield technology did not advance significantly as for example during the years 1909 to 1932, the period chosen by Nerlove (11, p. 196). During those years yields per acre remained, except for annual fluctuations, virtually constant (12, p. 19). If crop production of more recent decades is to be analyzed change in crop yield technology can be no longer ignored. Obstacles to more realistic supply analysis, succinctly defined by Nerlove, need to be removed.

Millions of dollars are spent annually by the U.S. Government on agricultural adjustment and development. To allocate these funds efficiently a better knowledge of the dynamic forces of agricultural supply is invaluable. Had it not been for advances in crop yield technology the present surplus problems might well be nonexistent. For long-run policy decisions economic analysis of crop yield technology is essential. Analysis of the past can provide guide lines for future policy. The present study concentrates almost exclusively on quantification and economic analysis of U.S. crop yield technology. Obstacles to such analysis are formidable if nothing less than the ideal solution is acceptable. However in economic science the perfect solution can rarely if ever be attained. Indeed, approximations may be quite sufficient if they provide some further insights into the dynamics of agricultural supply.

It is the objective of the present analysis to quantify the causative forces of crop yield technology and to analyze their impact on U.S. food and feed grain production. Essentially the analysis is based on time series data of the past two decades. The common practice of specification of technology by inserting a time trend variable in time series analysis is regarded as a feature of expedience here. Time is a necessary but not a sufficient condition for technological change. It does not specify the cause of technological change. Assuming time series data of variables of crop yield technology can be developed, statistical problems of estimating their individual effects on crop yields arise. Johnson and Gustavson commented on these problems as follows:

> "But even if we had accurate measures of all the variables that we believed were important, we would still be confronted with problems difficult of solution. A real source of difficulty in analysis has been alluded to above--in actual practice many variables tend to change at the same time. And the changes in the variables are highly correlated. The increased use of tractors, fertilizer, and hybrid corn from the early 1930's to the present time have tended to be parallel increases. Consequently it is extremely difficult to isolate the effects of each of these important changes.
>
> If one were to calculate a regression of yields, even after adjustment for the effects of weather, for the nation as a whole over a period of years on such variables as annual fertilizer use, the degree of mechanization, the percentage of land seeded or planted to improved varieties, the amount of summer fallow, and similar variables, one would be able to obtain a relatively large corelation coefficient. But the measures of the effects of each of the so-called independent variables would be difficult, if not impossible, to interpret" (7, pp. 60, 61).

Why would it be so difficult, if not impossible, to interpret measures of individual effects? If economic models are logically correct it ought to be quite easy to interpret their statistical estimates. However, it is well known that high correlation among independent variates may cause instability in regression coefficients and thus lead to nonsensical estimates. The difficulty of interpreting such results consists of trying to make sense out of nonsensical results.

Several months ago Zvi Griliches published estimates on aggregate production functions for U.S. agriculture (13, pp. 419-428). His estimates were derived from cross-sectional data of 68 production regions of the year 1949. He employed the production function technique because in the words of the author, "Many of the questions related to the measurement and sources of technical change can be best analyzed and answered within an explicit production function framework" (13, p. 419). According to Griliches "The main difficulty faced in this study was the lack of appropriate quantity data for many of the variables. ...The choice of variables to be included was largely dictated by the availability of the data (13, p. 420). In his conclusion he states, "Each of the original 'hunches' seems to have been confirmed by our results" (13, p. 427). With regard to Griliches' analysis selected comments of discussant George G. Judge are of relevance here:

> "Although the correlation matrix for the 'independent' variables is not given, I would suspect from past experience that these variables are subject to high intercorrelations. If this suspicion is true, then the problem of multicolinearity rears its ugly head and the parameter estimates may be highly disturbed.
>
> The high R^2 value for each equation indicates that it has accounted for almost the complete variation in the dependent variables employed. Although the small residual errors are impressive

> at first glance, one wonders just how seriously they should be taken As Theil has remarked, any econometric venture is an essay in persuasion, and I think it is fairly widely recognized now that the fact that equations fit the data from which they were derived is a test primarily of the skill and patience of the analyst and not a test of the validity of the equations for any broader body of data. When one sees such identifying numbers on the equations as R85 and U17, the question as to the number of alternative formulations tried is raised. Also, if the same set of data is used in various formulations, then certain problems of making reliability statements etc., are called to attention (14, pp. 431, 432).

Judge suspected that high correlation among independent variables, i.e. multicollinearity, may have resulted in highly disturbed parameter estimates. His question as to how many alternative formulations were tried but not published may reflect the significance of the problem of multicollinearity in econometric analysis and currently practised procedures of expedience.

Whenever statistical regression estimates can be clearly identified as nonsensical results the solution to the problem may be close at hand. Objectively, nonsensical regression estimates can only be identified as such if a priori knowledge can provide much more reliable estimates. For example if time series regression estimates of crop fertilizer response of a given state turn out to be negative while numerous fertilizer experiments show positive response on all soil types, for the same crop, in the same state then the time series estimates can be rejected as nonsensical.[1] To try alternative formulations of state regressions until statistical estimates so derived coincide with a priori information can hardly be considered a gain in knowledge. From a logical point of view an alternative approach is more acceptable. Fertilizer response estimates are

[1]An example of such nonsensical regression results is presented in Chapter IV, herein.

derived from a priori information first and then incorporated in the time series analysis. This procedure is followed here. On the basis of experiment station tests, crop yield effects of selected variables are estimated separately and then combined with other variables for estimation of overall effects of crop yield technology on state crop yields. The risk of such a method has been pointed out by Johnson and Gustavson:

> "If we consider each of the variables separetely, but without effectively controlling the changes in the others, we will surely overestimate the influence of each. We are likely to find ourselves in the embarrassing position of having found an 'explanation' for a greater increase in yield than actually occurred" (7, p. 60).

Admittedly this risk exists but it is accepted here. Results of this study appear to deflate the size of this risk factor.

An attempt is made in this study to specify those crop yield variables which are generally considered most important. They are variables quantifying crop yield effects of plant breeding and fertilization in combination with weather and acreage effects. In addition a net-time trend variable is used to measure the significance of other but unidentified causes of long-run crop yield change. On the basis of this information crop production and crop supply functions are estimated. They are used to quantify change in crop supply due to technology. Perhaps most importantly an attempt is made to measure the magnitude of the economic incentive to greater production as provided by a modern capitalistic pricing system. For years the U.S. government has sponsored research programs aimed at advancing agricultural production technology. Results of this research have been available to farmers at low cost and have been widely and rapidly adopted. It will be shown subsequently that it was this unique combination of private enterprise and government sponsored research which induced U.S. farmers to produce food more efficiently than ever before. It is hoped that the results of this analysis will be of interest to research workers in the field of agricultural adjustment and development.

This study covers changes in crop yield technology of major crops and production regions of the United States over the last two decades. It includes the crops: corn, wheat, oats, barley, grain sorghum, soybeans, cotton, flax, and tame hay. Crop yield change of the Corn Belt, and Lake States, Northern Plains, Southern Plains, and Delta States is analyzed state by state. Results are presented on state, regional or total aggregate basis whichever appears most adequate. Refinement of data and econometric analysis is limited to essential requirements. The theoretical framework of the economic analysis is outlined first. Empirical procedures for estimation of crop yield variables follow next. Later state crop production functions are estimated and crop supply functions are derived. Actual and normative supply quantities are compared last.

CHAPTER II

THEORETICAL FRAMEWORK OF ANALYSIS

In this study relationships between crop yield technology and agricultural supply are analyzed. The theory of the firm is used as framework of analysis as it was assumed that aggregate production of U.S. agriculture can be decomposed into outputs of homogeneous production units. The theory of the firm can be applied in terms of classical marginal analysis or in terms of programming analysis. Both approaches are complementary and choice of method depends primarily on objectives and degree of refinement (15, p. 608). Programming is ideally suited for short run economic analysis where production restrictions are predominant. For study of the long run, classical marginal analysis may suffice because features of technological change can be readily incorporated and the multiplicity of short run restrictions diminishes. It is recognized that programming analysis may provide significant refinements in long run and macroeconomic analysis but first approximations are of primary interest here. If desired, results of the present study can be used later for programming analysis.

Classical marginal analysis is couched in terms of production function analysis and can be conveniently described in mathematical terminology. Criteria of efficient resource allocation are the same for all production functions irrespective of algebraic form. For purpose of illustration a Cobb-Douglas production function is used here. The same type of function was adopted for the empirical analysis because of its applicability and simplicity.

For constructing the economic model a one-product firm is considered first. It is assumed the firm operates under conditions of perfect competition. All relevant market prices and production functions are known with certainty and remain unchanged over time. The firm produces one product by use of n-resources on the basis of production function (2.1)

$$Y = b_0 x_1^{b_1} x_2^{b_2} \ldots x_j^{b_j} \ldots x_n^{b_n} = b_0 \prod_j^n x_j^{b_j} \qquad (2.1)$$

where Y is quantity of product produced; $x_1, \ldots, x_n$ are the quantities of each of n resources employed in the production process. The marginal productivity of any factor x_j of production is

$$\frac{\partial Y}{\partial x_j} = b_j \, Y/x_j \qquad (2.2)$$

which describes change in output Y due to a small change in resource use x_j while use of all other resources remains unchanged. The b_j- coefficients in functions 2.1 and 2.2 are related to the elasticity of production, a measure of relative change in output Y due to an equi-proportionate change in all resource inputs x_j. If resource inputs are increased proportionately the increments may be denoted by $m \cdot x_j$. Letting all increments $m \cdot x_j$ equal dx_j the change in output becomes dY and the elasticity of production is (17, p. 17):

$$e = \frac{dY}{Y} \Big/ \frac{dx_j}{x_j} = \frac{dY}{Y} \Big/ m. \qquad (2.3)$$

The total derivative of production function 2.1 is:

$$dY = \sum_j^n \frac{\partial Y}{\partial x_j} dx_j. \qquad (2.4)$$

Substituting dY from equation 2.3 into 2.4 leads to equation 2.5.

$$e = \sum_{j}^{n} \frac{\partial Y}{\partial x_j} \frac{x_j}{Y} \tag{2.5}$$

Applying formula 2.5 to production function 2.1 defines the elasticity of production as in 2.6.

$$e = \sum_{j}^{n} b_j \tag{2.6}$$

According to 2.6 the elasticity of production of function 2.1 is the sum of the b-coefficients. It is assumed that the elasticity of production is smaller than unity, i.e. relative changes in resource use do not change output in equal or greater proportions. This assumption implies diminishing returns to scale which can be justified on empirical grounds. Moreover it is assumed that the b_j-coefficients are positive rather than negative, a necessary condition for profitable resource use.

Resources are allocated most efficiently among alternative uses if net revenue is maximized. This definition corresponds to equation 2.7 where

$$\frac{\partial R}{\partial x_j} = \frac{\partial}{\partial x_j} \left(P_y\, b_o \prod_{j}^{n} x_j^{b_j} - \sum_{j}^{n} P_j\, x_j\right) = 0 \tag{2.7}$$

R is net revenue, and P_y and P_j are unit prices of product Y and resource inputs x_j respectively. Net revenue is maximized with respect to each resource and can not be increased by reallocation of resource inputs. Algebraically conditions of optimum resource use follow from 2.7 and are represented by 2.8 and 2.9.

$$\frac{\partial R}{\partial x_j} = b_o\, b_j\, \Pi\, x_j^{b_j} \;/\; x_j = \frac{P_j}{P_y} \tag{2.8}$$

$$\frac{\partial x_j}{\partial x_k} = \frac{b_k\, x_j}{b_j\, x_k} = \frac{P_k}{P_j} \tag{2.9}$$

According to equation 2.8 conditions of optimum resource allocation are met if marginal productivities equal resource-product price ratios. If this equality is achieved marginal rates of substitution between any two resources equal their (inverse) price ratios as shown in 2.9.

Resource quantities demanded for optimum resource use can be derived from 2.8 above.[1] The system of equations 2.8 is restated in logarithmic form explicitly in 2.10 and by matrix notation in 2.11.

$$\begin{array}{lllll} (b_1-1) \log x_1 + \ldots + b_j & \log x_j + \ldots b_n & \log x_n = \log\,(P_1/P_y b_o b_1) \\ b & & \\ b_j \quad \log x_1 + \ldots + (b_j-1) & \log x_j + \ldots b_n & \log x_n = \log\,(P_j/P_y b_o b_j) \\ b_n \quad \log x_1 + \ldots + b_j & \log x_j + \ldots (b_n-1) & \log x_n = \log\,(P_n/P_y\; b_o b_n) \end{array} \tag{2.10}$$

$$(B-I)\, X = AX = C \tag{2.11}$$

Notations in 2.10 are the same as before. In 2.11 the letter B denotes the n·n coefficient matrix, I is an n·n identity matrix, X and C are column vectors and A stands for the (B-I) matrix. According to previous assumptions all elements of matrix B are positive, greater than zero but smaller than unity and sums of row elements of matrix B are also between

[1]Alternative methods of derivation can be used. The method employed here is useful for subsequent discussion.

zero and one. Assuming matrix A is non-singular, i.e. det A $\neq$ 0, then system 2.10 has a unique solution. The solution is found by use of an A_j matrix which is formed by substituting the j^{th} column of matrix A by vector C. Applying Cramer's Rule (17, p. 69) elements of vector X are evaluated in terms of determinants as in 2.12 and 2.13 where 2.13 is the antilog of 2.12 and represents optimum use of resource x_j.

$$\log x_j = \frac{\det A_j}{\det A} \tag{2.12}$$

$$x_j = \frac{b_j}{P_j} (b_0 P_y)^{\frac{1}{1-\sum b_j}} \prod_{j}^{n} \frac{b_j}{P_j}^{\frac{b_j}{1-\sum b_j}} \tag{2.13}$$

Assuming varying resource prices equation 2.13 becomes the resource demand function. The quantity demanded varies inversely with resource price and directly with product price. Elasticities of factor demand are 2.14, 2.15 and 2.16. These equations specify relative changes in resource

$$Ed_j = \frac{\partial x_j}{\partial P} \cdot \frac{P_j}{x_j} = -(1 - \frac{b_j}{1 - \sum b_k}) \tag{2.14}$$

$$Ed_{k\neq j} = \frac{\partial x_j}{\partial P_k} \cdot \frac{P_k}{x_j} = -(\frac{b_k}{1 - \sum b_j}) \tag{2.15}$$

$$Ed_y = \frac{\partial x_j}{\partial P_y} \cdot \frac{P_y}{x_j} = \frac{1}{1 - \sum b_j} \tag{2.16}$$

quantities x_j demanded depending on relative price changes of resource x_j, of a different resource x_k, and of product Y. Resource demand elasticities 2.14 and 2.15 are negative. Price changes in resource j affect demand quantities of resource j more than proportionately as indicated by 2.14. Price changes of other resources k $\neq$ j affect demand quantity of j also but the effect is weaker as reflected by elasticity 2.15. In contrast to resource demand elasticities 2.14 and 2.15, the cross-elasticity of resource demand due to a change in product price is positive and dependent on the sum of the coefficients only. All elasticities are constants, a characteristic feature of production function 2.1.

The product supply function can now be derived by replacing the x_j-values of 2.1 by optimum x_j-values of 2.13 and subsequent simplification.

$$Y = (b_o P_y)^{\frac{b_j}{1 - \sum b_j}} \prod_j^n \frac{b_o b_j}{P_j}^{\frac{b_j}{1 - \sum b_j}} \qquad (2.17)$$

$$E_{sy} = \frac{\partial Y}{\partial P_y} \cdot \frac{P_2}{Y} = \frac{\sum b_j}{1 - \sum b_j} \qquad (2.18)$$

$$E_{sj} = \frac{\partial Y}{\partial P_j} \cdot \frac{P_j}{Y} = \frac{-b_j}{1 - \sum b_j} \qquad (2.19)$$

According to equation 2.17 supply quantities are directly related to product prices and inversely related to factor prices. Correspondingly supply elasticity 2.18 is positive and 2.19 is negative.

Next, the theoretical framework is expanded to include the case of the multi-product firm. In contrast to the single-product firm the multi-product firm produces not one but m products on the basis of m production functions. It is assumed the multi-product firm used the same resource factors in the production process of each product. However, joint production in which a single production function yields more than one product is excluded. Using similar notations as before, production of the multi-product firm is defined by equation 2.20 where

$$Y = \sum_i^m Y_i = \sum_i^m b_{io} \prod_j^n x_{ij}^{b_{ij}} \qquad (2.20)$$

total production is denoted by Y, individual products are Y_i and the j^{th} resource quantity used for production of the i^{th} product is x_{ij}. The right hand side of equation 2.20 is the sum of m production functions. Individual production functions, each representing a different enterprise, are of the same form as production function 2.1 described previously. The same resource factors are used in all enterprises, i.e. the j^{th} resource used for production of one product could alternatively be used for production of another product. Again, conditions of pure competition, perfect knowledge and resource use at market prices are assumed. Returns to scale as defined in 2.6 are diminishing for all enterprise production functions.

Maximization of net revenue of the multi-product firm follows the pattern of analysis of the single product firm. Mathematical solution of the problem requires evaluation of differential quotient 2.21.

$$\frac{\partial R}{\partial x_{ij}} = \frac{\partial}{\partial x_{ij}} \sum_{i}^{m} (P_{yi}\, b_{io} \prod_{j}^{n} x_{ij}^{b_{ij}} - P_j\, x_{ij}) = 0 \qquad (2.21)$$

$$\frac{\partial Y_i}{\partial x_{ij}} = \frac{P_j}{P_{yi}} \qquad (2.22)$$

$$\frac{\partial x_{ij}}{\partial x_{ik}} = \frac{P_k}{P_j} \qquad (2.23)$$

$$\frac{\partial Y_i}{\partial Y_1} = \frac{P_{y1}}{P_{yi}} \qquad (2.24)$$

It involves solution of a system of m•n equations, one system of n equations for each of m enterprises. Conditions of optimum resource use follow from 2.21 and are stated in 2.22 to 2.24. They require that (a) marginal productivities of resource inputs equal resource-product price ratios in each enterprise, (b) marginal rates of substitution between any two resource inputs equal their (inverse) price ratios in each enterprise, and (c) marginal rates of substitution between any two product outputs equal their (inverse) product price ratios.

Optimum resource allocation of the multi-product firm as defined by 2.21 is perhaps intuitively self-evident but for completeness and further analysis it is determined algebraically. Equations in 2.21 are transformed into logarithmic form. The resulting $[A_i]$ matrix 2.25 is composed of m sub-matrices

$$\begin{bmatrix} A_1 & \cdots & 0 \\ \vdots & A_i & \vdots \\ 0 & \cdots & A_m \end{bmatrix} \begin{bmatrix} X_1 \\ \vdots \\ X_i \\ \vdots \\ X_m \end{bmatrix} = \begin{bmatrix} C_1 \\ \vdots \\ C_i \\ \vdots \\ C_m \end{bmatrix} \tag{2.25}$$

A_1, A_2,..., A_m on the diagonal, each of which contains n·n elements just like the A matrix in 2.11. Correspondingly the X_i and C_i vectors are composed of m subvectors each containing n elements. The determinant of the $[A_i]$ matrix is the product of the determinants of matrices A_1, A_2, ..., A_m (17, pp. 42-44). The solutions for x_{ij} are found by application of Cramer's rule as shown in 2.26 and 2.27.

$$x_{ij} = \frac{\det [A_{ij}]}{\det [A_i]} = \frac{\det A_{ij}}{\det A_i} \tag{2.26}$$

$$x_{ij} = \frac{b_{ij}}{P_j} (b_{oi} P_{yi})^{\frac{1}{1-\sum b_{ij}}} \prod_{j}^{n} \frac{b_{ij}}{P_j}^{\frac{b_{ij}}{1-\sum b_{ik}}} \tag{2.27}$$

Equation 2.27 quantifies optimum input of the j^{th} resource in the i^{th} enterprise of the multi-product firm. Except for subscript i, equation 2.27 is identical to equation 2.13 which quantified optimum use of the jth resource of the single product firm. It follows that resource demand functions and product supply functions derived for individual products are identical to resource demand functions and product supply functions derived for a combination of products provided the specified assumptions apply. However, results are different if the key assumption of unrestricted resource use is removed.

Capital limitations, imposed by internal or external capital rationing, restrict resource use, reduce resource demand and product supply. In mathematical terminology optimum resource allocation under limited capital conditions involves solution of a constrained maximization problem (18, p. 69) as for example in the case of the single product firm in 2.28 where C represents the limited amount of capital available for purchase of resource inputs x_j at prices P_j, μ is an undetermined Lagrange multiplier to be evaluated, R means net revenue, P_y is product price, b_o is a constant and b_j are exponents of the production function where j goes from 1 to n as before. The condition for optimum resource allocation is derived from 2.29, a system of n+1 equations, and given in 2.30. According to 2.30 resources are optimally allocated if the marginal value product-factor price ratio equals μ for all resources. After substituting P_j of 2.30 into the last equation of 2.29 the system of equations can be solved as before. The solutions are equations 2.31 and 2.32.

$$R = P_y b_o \prod_j^n x_j^{b_j} + \mu (C - \sum_j^n P_j x_j) \qquad (2.28)$$

$$\frac{\partial R}{\partial x_j} = P_y b_o b_j \prod_j^n (x_j^{b_j} / x_j) - \mu P_j = 0 \qquad (2.29)$$

$$\frac{\partial R}{\partial \mu} = C_o - \sum_j^n P_j x_j = 0$$

$$\mu = P_y \frac{\partial Y}{\partial x_j} / P_j \tag{2.30}$$

$$x_j = \frac{b_j}{\mu P_j} (b_o P_y)^{\frac{1}{1-\sum b_j}} \prod_{j}^{n} \frac{b_j}{\mu P_j}^{\frac{b_j}{1-\sum b_j}} \tag{2.31}$$

$$Y = b_o P_y^{\frac{\sum b_j}{1-\sum b_j}} \prod_{j}^{n} \frac{b_o b_k}{P_k}^{\frac{b_j}{1-\sum b_j}} \tag{2.32}$$

$$E_{sj} = \frac{1}{\mu} \left(\frac{-b_j}{1-\sum b_j} \right) \qquad E_{dj} = -\frac{1}{\mu} \left(1 + \frac{b_j}{1-\sum b_j} \right) \tag{2.33}$$

$$\mu = b_o P_y \left(\frac{C}{\sum b_j} \right)^{\sum b_j - 1} \prod_{j}^{n} \left(\frac{b_j}{P_j} \right)^{b_j} \tag{2.34}$$

When capital is limited the value of μ is greater than unity and consequently factor demand x_j in 2.31 and product supply in 2.32 are reduced. Since capital use is restricted to C, output becomes a function of the limited amount of capital. Given production function and limited capital, the firm optimizes resource allocation by substituting resources according to resource price-ratios irrespective of product price. Consequently the supply elasticity of product price is reduced to zero. Supply elasticities of factor prices and demand elasticities for factors of production are both negative. In contrast to corresponding elasticities under unrestricted resource use, the elasticities under 2.33 are numerically smaller by factor $1/\mu$. The magnitude of μ, as listed in 2.34, is a function of production coefficients, the amount of capital available, resource and product prices. Under conditions of restricted capital use reduction in price response varies directly with capital restriction and product price, and it varies inversely with changes in resource prices. In all cases, capital restrictions reduce resource demand and product supply of the single product firm.

Capital restrictions have a unique effect on distribution of resources among enterprises multi-product firms. As before the multi-product firm produces m products by use of n resources in m enterprises. All resources can be employed in varying amounts in each enterprise. The objective of the multi-product firm is to maximize net revenue as specified in 2.35. Conditions of optimum resource allocations are

$$R = \sum_{i}^{m} (P_{yi}\, b_{io} \prod_{j}^{n} x_{ij}^{b_{ij}}) + \lambda (C - \sum_{i}^{m}\sum_{j}^{n} P_i\, x_{ij}) \tag{2.35}$$

$$\frac{\partial R}{\partial x_{ij}} = P_{yi}\, b_{io}\, b_{ij} \prod_{j}^{n} (x_{ij}^{b_{ij}} / x_{ij}) - \lambda P_j = 0 \tag{2.36}$$

$$\frac{\partial R}{\partial \lambda} = C - \sum_{i}^{m}\sum_{j}^{n} P_i\, x_{ij} = 0$$

given by 2.35 and 2.36 where algebraic notations are identical to those used in 2.29 above except for λ, an undetermined Lagrange multiplier. The equality in 2.36 represents a system of n·m equations and one additional equation to assure that capital input does not exceed capital restriction C. Due to capital restriction resource allocation between enterprises is no longer independent. Resource demand, product supply and price response are lowered by factor $1/\lambda$, where λ is a function of available capital, production coefficients and resource prices but also a function of all product prices. Therefore, under capital restrictions, resource demand and product supply quantities derived for individual products of single product firms differ from resource demand functions and product supply functions derived for combinations of products of multiproduct firms. Differences in price response are attributable to differences in product prices, factor prices and production coefficients of alternative enterprises. Reduction in demand due to capital restrictions can be quantified by solving equations 2.36 by successive iteration, e.g. by application of the Newton-Raphson method (19, p. 187). Alternatively and more efficiently solutions can be found by curvilinear programming (20, pp. 223-237). Neither method will be employed here. It will suffice to point out that restricted output optima of different enterprises may approximate unrestricted output optima to varying degrees.

Technological innovations alter existing production functions. Marginal productivities are changed, resource demand and product supply functions are shifted. In Hicksian terminology innovations are said to be neutral when they raise marginal productivities of all resources in equal proportions (21, p. 139). This implies that after technological innovation factors of production are combined optimally in the same proportions as before they can be employed to produce a greater output at the same input level or to produce the same output at a proportionately and uniformly lower input level. A neutral technological innovation is incorporated in production function 2.37 by factor T_1 which changes marginal productivities of resources x_j by equal proportions but does not alter rates of substitution between them. In contrast other technological innovations, e.g. T_2 in 2.37, affect rates of substitution between factors of production. Resources need to be reallocated according to the

$$Y = T_1 T_2^t b_o \prod_j^n x_j^{b_j} \tag{2.37}$$

principles outlined before. At times some resource inputs may be displaced by others or entire production functions may be replaced. In this study technological change is assumed to alter existing production functions as illustrated in 2.37. Consequently the impact of technological change can be analyzed in the general framework discussed before.

Under certain conditions contributions of individual factors to changes in output can be quantified. If a production function consists of n input variables and if a given output Y_o is defined by resource input levels $(x_1, \ldots, x_j, \ldots, x_n)_o$, a change in output ΔY_o can be represented by changes in inputs Δx_j in terms of Taylor's series as in 2.38. Taylor's expansion in 2.38 is valid provided the production function has finite and continuous derivatives of all orders at input levels $(x_1, \ldots, x_j, \ldots, x_n)_o$ and the remainder term R_r (Δx_j) approaches zero as r goes to

$$Y_o + \Delta Y_o = Y_o + \sum_j^n (\frac{\partial Y}{\partial x_j})_o \Delta x_j + \frac{1}{2!} \sum_j^n (\frac{\partial^2 Y}{\partial x_j^2})_o \Delta x_j + \ldots + R_r(\Delta x_r) \tag{2.38}$$

$$(\frac{\partial Y}{\partial x_j})_o = b_o Y_o / x_{jo} \tag{2.39}$$

$$\Delta Y = \sum_j^n (b_j Y_o / x_{jo}) \Delta x_j + \frac{1}{2!} \sum_j^n (b_j(b_j - 1) Y_o / x_j^2) \Delta x_j^2 + \ldots \tag{2.40}$$

infinity (22, p. 458). In the case of the Cobb-Douglas function these conditions can be met if exponents b_j are between zero and one, if all input levels x_j are non-zero at the original output level Y_o and if the change Δx_j is smaller than the original input level x_j. Assuming these conditions can be satisfied, contributions of individual resource inputs and technological innovations to change in output are approximated by 2.40. Equation 2.40 is derived from 2.38 by making use of relation 2.39. As is evident from 2.40, approximate change in output is attributed to individual resource factors according to marginal productivities and change in resource use. Further expansion of series 2.40 involves terms of higher powers and product terms. The product terms can be considered as interactions between resource inputs. By taking additional terms of the series into account the degree of accuracy can be increased as desired.

Theoretical considerations presented in this chapter serve as general framework for subsequent analysis. In the empirical analysis variables of technological change are incorporated in crop production functions. Contributions of individual variables to changes in crop yields are estimated for states, regions and in aggregate. Annual and cumulative yield effects of regional specialization are quantified. State and aggregate crop yields are compared to unrestricted economic optimum yields. Theoretical aspects of estimation procedures are discussed whenever deemed necessary.

CHAPTER III

ESTIMATION OF CROP YIELD VARIABLES

Crop yield variables were estimated for measuring the yield impact of adoption of new crop varieties, increased fertilizer application, varying weather conditions and other forces affecting crop yields in individual states. Estimation of crop yield variables is presented in terms of data sources, procedural outlines and empirical illustrations.

Crop Variety Index

To estimate the effect of crop variety improvement on state crop yields two sets of information were taken into account: (1) results of crop variety yield tests conducted at experimental stations and (2) estimates of acreage distributions of crop varieties. Over the last two decades research workers at agricultural experiment stations have tested yield performance of numerous crop varieties. Many of the crop yield tests were conducted by state and federal research workers cooperatively in nationally coordinated crop breeding nurseries. Results of these tests have been used extensively during the course of this study. A twenty year summary of "Hard Red Winter Wheat Improvement in the Plains" has been published by the U.S.D.A. (23). This summary contains annual yield test results of hard red winter wheat varieties of more than 30 experimental stations. It is based on data collected under the national plant breeding program and representative of the information used here. Information on the acreage distribution of individual crop varieties is not as plentiful. Data on the distribution of wheat varieties in the United States have been published at regular intervals by the U.S. Department of Agriculture. Some additional information on acreage distribution of crop varieties has been published by some states and for some crops. Most of the information on annual acreage distributions of crop varieties was obtained by contacting research workers engaged in crop variety improvement programs of individual states. Related references are listed in Chapter VIII.

Crop variety indices were estimated by crops and states. As a first step relative test yields were computed for individual varieties according to formula 3.1 where subscripts i, j, and l denote variety, years and location of experiment station respectively. The ratio

$$v_i = \left(\sum_j^m \sum_l^k \left(y_{ijl} / y^*_{jl} \right) \right) / (m \cdot k) \tag{3.1}$$

y_{ijl} / y^*_{jl} represents the yield of variety i relative to the yield of the check variety in year j at location l. Relative test yields v_i were estimated by summing up and averaging the yield ratios of variety i over the check variety for identical station-years. At times relative test yields of crop varieties were estimated according to formula 3.2

$$v_i = \left(\sum_j^m k_j \left(\sum_l^{k_j} y / \sum_l^{k_j} y^*_{jl} \right) \right) / \sum_j^m k_j \tag{3.2}$$

which implies estimation of v_i by averaging annual ratios of the sums of station yields of variety i over the check variety. If the number of station locations varied from year to year the annual ratios were weighted by k_j, the number of annual station locations. Here, again, yields of variety i were compared to those of the check variety for identical station years. Both formulas were based on the assumption that there was a constant yield ratio between any individual variety i and the check variety. Since formula 3.1 was commonly used by agronomists for comparing yield performance of individual varieties in crop variety nursery tests it was adopted in this study whenever available. Computationally formula 3.2 was less time consuming than formula 3.1 and was often applied when relative test yields of individual varieties were not listed in the nursery reports. If the assumption of a constant yield ratio holds both formulas result in identical values for variety yield performance.

As a second step acreage distributions of crop varieties were taken into account. For this purpose relative test yields of individual varieties were aggregated into annual state crop variety indices V_j according to formula 3.3 where v_i represents the relative test yield of

$$V_j = \sum_{i}^{n} v_i r_{ij} \tag{3.3}$$

variety i and r_{ij} denotes relative acreage of cropland planted to variety i in year j. In most cases only the more important varieties were incorporated in the computations of the state crop variety indices. Consequently formula 3.3 was modified as in 3.4 which is the same as 3.3 except for adjustment factor ($\sum_{i}^{n} r_{ij}$) which corrects for crop varieties

$$V_j = \left(\sum_{i}^{n} v_i r_{ij} \right) / \left(\sum_{i}^{n} r_{ij} \right) \tag{3.4}$$

not included in index V_j. This adjustment factor is exact if varieties excluded from index computations perform as well as the average of all varieties included. Implicitly it was also assumed that differences in relative yields of varieties in different goegraphic areas of a state were adequately reflected in the experiment station results. Varieties of some crops, e.g., soybeans, were more sensitive to differences in location than varieties of other crops. Where considered important, adjustment procedures were incorporated. All state crop variety indices were made comparable over time by using values of the years 1947-1949 as base period values.

Computational procedures leading to estimation of the Kansas wheat variety index may illustrate how crop variety indices were estimated. For more than 20 years wheat variety yield tests were conducted at four locations in Kansas: Hays, Colby, Manhattan and Garden City. In Table 3.1 results of yield tests of 18 winter wheat varieties are summarized. Yields of each variety were compared to yields of check variety Kharkof at each location.[1] For example hard red winter wheat varieties Tenmarq and Kharkof were both tested at Station Hays for 21 years. The average yield ratio of these two varieties was 1.13, indicating that variety Tenmarq yielded 1.13 times as much as check variety Kharkof for identical station-years (Table 3.1, column 1). Correspondingly test results were evaluated at locations Colby, Manhattan and Garden City. At all four locations varieties Tenmarq and Kharkof were tested together in 72 variety yield tests. The average weighted yield ratio of Tenmarq over Kharkof was 1.15 as shown in column 6, Table 3.1. This weighted yield ratio is equivalent to value v_i in formula 3.2 and represents the relative

[1]For yield comparisons of varieties grown at Garden City variety Turkey was used as check variety prior to 1955. Yield differences between Kharkof and Turkey were considered insignificant.

Table 3.1. Summary of test plot yield comparisons of hard red winter varieties at four experiment stations in Kansas[a]

Variety	No. of Tests and Yield Comparisons								No. of Tests	% of Kharkof
	Hays		Colby		Manhattan		Garden City			
	(1)		(2)		(3)		(4)		(5)	(6)
Kanred	16	1.04	12	1.04	21	1.04	-	-	49	1.04
Turkey	23	.98	19	.98	27	1.04	18	1.03	87	1.01
Blackhull	21	1.06	12	1.05	17	1.10	10	1.15	60	1.08
Early Blackhull	21	1.19	12	1.02	17	1.13	13	1.15	63	1.13
Tenmarq	21	1.13	14	1.09	23	1.18	14	1.21	72	1.15
Kawvale	-	-	-	-	17	1.20	-	-	17	1.20
Chiefkan	13	1.26	9	1.10	10	1.23	9	1.20	41	1.20
Red Chief	13	1.10	12	1.06	15	1.07	13	1.15	53	1.09
Pawnee	17	1.16	15	1.10	21	1.39	18	1.06	71	1.19
Triumph	7	1.03	6	1.11	13	1.28	11	1.19	37	1.18
Comanche	18	1.14	16	1.07	21	1.28	18	1.29	73	1.20
Blue Jacket	6	1.05	4	.98	8	1.30	5	1.11	23	1.14
Wichita	14	1.11	15	1.09	19	1.28	16	1.17	64	1.17
Ponca	9	1.10	10	1.13	14	1.33	10	1.10	43	1.16
Kiowa	10	1.12	10	1.09	13	1.28	11	1.27	44	1.20
Bison	6	1.08	21	1.17	7	1.25	4	1.30	21	1.17
Kharkof	23	1.00	12	1.00	27	1.00	5	1.00	67	1.00
Concho	3	1.10	6	1.57	7	1.20	6	1.35	22	1.57
Total Number of Tests									885	

[a]Source: References; Wheat.

test yield of Tenmarq in Kansas test plot yield comparisons of wheat varieties. Relative test yields for other Kansas wheat varieties were computed in the same manner. In total 885 test yields were used for the computation of relative test yields of 18 wheat varieties in Kansas.

Percentage estimates of acreages planted to specified wheat varieties in Kansas are presented in Table 3.2. For example in the year 1929 winter wheat varieties Kanred, Turkey and Blackhull occupied 12.0, 48.0 and 33.4 percent of the Kansas wheat acreage respectively. Together these varieties occupied 93.4 percent of the wheat acreage, the remainder of 6.6 percent of the wheat acreage was planted to other varieties. Thirty years later, in 1959, the early varieties had been almost completely replaced by newer varieties which were adopted during the late forties and throughout the fifties. Numbers of tests and relative test yields of 17 wheat varieties, first presented in Table 3.1, are tabulated in Table 3.2. A weighted index was obtained by multiplying relative test yield values of individual varieties by their relative acreages. This weighted index was inflated by the reciprocal of the sum of the acreage percentages of specified varieties. For example the weighted index of the 1929-column is 97.03 and is multiplied by (100.0 / 93.4) which yields the Kansas wheat variety index of 1.039 for the year 1929. As mentioned before this adjustment procedure is based on the assumption that unspecified varieties performed as well as the average of the tabulated varieties. This assumption may not hold quite true in practice but as the relative acreage of the unspecified varieties is comparatively small and fairly constant over time, errors thus introduced may be considered insignificant. Acreage distributions of wheat varieties have been estimated at 5 year intervals. No attempt was made to obtain estimates of acreage distributions of wheat varieties for intervening years. Estimates of wheat variety indices for intervening years were simply derived by interpolation For most other crops annual estimates of acreage distribution of varieties were obtained. In all cases annual crop variety indices were divided by their 1947-1949 values, a procedure sesigned to make state crop variety indices comparable between states and crops. Both Kansas wheat variety indices, i.e. base Kharkof and base 1947-49, are shown in Table 3.2.

Coverage of the crop variety index analysis is summarized in Table

Table 3.2. Relative test yields, estimated percentage of wheat acreage planted to specified varieties and Kansas wheat variety index at 5-year intervals, 1929 to 1959[a]

Variety	Kansas Test Yields No. of Tests	Kansas Test Yields % of Kharkof	Estimated Percentage of Acreage Planted to Specified Varieties 1929	1934	1939	1944	1949	1954	1959
Kanred	49	1.04	12.0	10.4	4.5	2.7	.2	b	b
Turkey	87	1.01	48.0	44.3	28.9	14.7	1.7	.3	.3
Blackhull	60	1.08	33.4	34.9	31.0	15.5	3.6	.5	.2
Early Blackhull	63	1.13	b	.6	1.6	9.0	4.6	2.2	
Tenmarq	72	1.15		1.3	19.6	36.6	8.5	.1	1.2
Kawvale	17	1.20		.3	6.4	4.4	.7	.5	
Chiefkan	41	1.20			2.8	8.6	1.3	6.1	b
Red Chief	53	1.09				4.4	3.9	29.0	.2
Pawnee	71	1.19				b	36.0	7.4	11.2
Triumph	37	1.18				.1	6.4	11.1	14.8
Comanche	73	1.20				.1	20.8	3.3	8.9
Blue Jacket	23	1.14					.7	24.3	b
Wichita	64	1.17					9.4	2.4	22.7
Ponca	43	1.16						8.1	11.6
Kiowa	44	1.20							13.8
Bison	21	1.17							9.8
Concho	22	1.33							2.0
All Others			6.6	8.2	5.2	3.9	2.2	4.2	3.3
Total			100.0	100.0	100.0	100.0	100.0	100.0	100.0
Winter Wheat Variety Index									
Base: Kharkof			1.039	1.042	1.076	1.084	1.117	1.170	1.183
Base: 1947-49			.896	.899	.935	.963	1.009	1.014	1.020

[a]Source: References; Wheat, Kansas. For comparison see Appendix Tables A.7 and A.55.

[b]Less than .5 percent.

3.3. It shows time periods covered by the analysis, number of varieties included and total numbers of variety tests by crops and regions. Most crops could only be analyzed over the last two decades because uniform cooperative nursery tests were not conducted during the early thirties and it appeared questionable if reliable estimates of the acreage distributions of individual crop varieties could have been made for earlier years. The number of crop varieties and of crop variety yield tests varied between crops and states. Usually experimental stations conducted a more intensive variety testing program for those crops which were more important to state farm income than others. Also the overall crop variety testing program of some states appeared to differ in terms of total number of variety test conducted. For example less information was found on crop yield tests of states in the South East than in the Corn Belt. In Table 3,3 the coverage of the crop variety index analysis is restricted to those states which were included throughout this study. Results of more than 28,000 variety tests were used to estimate crop variety indices. Additional crop variety indices were computed for selected crops and states in the North East, Appalachian, South East and Mountain Region. They are listed in Appendix A where all crop variety indices, relative test yields and acreage distributions are tabulated by crops and states.

Oats and soybean variety test results were aggregated on regional rather than state basis for reasons of computational convenience. For constructing oats variety indices check variety Andrew was used as it was grown as a check in tests of the Corn Belt, the Lake States and the Northern Plains. Texas and Oklahoma oats variety indices were computed

Table 3.3. Summary of crop variety indices in terms of state and regional coverage, period of years, number of varieties and number of tests[a]

State / Region	Wheat Years	Wheat Number of Var's	Wheat Number of Tests	Oats Years	Oats Number of Var's	Oats Number of Tests	Soybeans Years	Soybeans Number of Var's	Soybeans Number of Tests	Cotton Years	Cotton Number of Var's	Cotton Number of Tests
Ohio	39-60	9		42-60	23		41-60	17				
Ind.	39-60	11		42-60	19		41-60	18				
Ill.	29-60	25		42-60	30		41-60	16				
Iowa	27-60	16		42-60	17		41-60	15				
Mo.				42-60	18		41-60	20				
Corn Belt			1132			1408			5065			
Mich.	39-60	11		42-60	16		42-60	9				
Wisc.	42-60	13		42-60	21		42-60	14				
Minn.	29-60	18		42-60	19		42-60	16				
Lake States			1206			612			295			
N. Dak.	29-60	17		42-60	24							
S. Dak.	29-60	17		44-60	19							
Nebr.	29-60	19		42-60	28							
Kans.	29-60	17		42-60	14							
N. Plains			3403			1545						
Texas	31-60	16		42-60	11					40-60	20	
Okla.	31-60	15		40-60	25					30-60	15	
S. Plains			1354			1622						2325
Ark.										41-60	12	
Miss.										39-60	15	
Delta States												1960
Total			7095			5187			6230			4285

[a]Source: References; CROPS.

Table 3.3 (Continued)

State Region	Barley Years	Barley Number of Var's	Barley Number of Tests	Flax Years	Flax Number of Var's	Flax Number of Tests	Grain Sorghum Years	Grain Sorghum Number of Var's	Grain Sorghum Number of Tests	Total Number of Tests
Minn.	43-60	12		44-61	20					
N. Dak.	43-61	14		44-61	19					
S. Dak.	43-60	16		39-60	19					
Nebr.	40-61	6					39-61	12		
Kans.							39-60	23		
Texas							39-60	14		
Okla.							44-60	7		
Total			2106			1157			2526	Number of All Tests 28,586

individually using New Nortex and Wintook as check varieties respectively. The fact that Andrew was used as a check variety in 13 states appears to indicate that oats varieties are not as sensitive to differences in location as varieties of other crops.-- Soybeans were aggregated by regions and maturity groups. Under the U.S. Cooperative Test Program soybean varieties were tested by maturity groups ranging from 00 to VIII. Check varieties were selected for individual maturity groups within regions. For example in soybean variety tests of Corn Belt states varieties Earlyana, Richland, Dunfield and Chief were chosen as primary check varieties for maturity groups I, II, III and IV respectively. They were selected because they could be used for variety yield comparisons in 1406 out of 1689 tests. For the remaining tests secondary check varieties Blackhawk, Hawkeye, Shelby and Clark were used for relative yield comparisons. Relative test yields of individual soybean varieties were computed by comparing their yields to those of primary and secondary varieties. Whenever secondary check varieties were used for comparisons relative yields between primary and secondary varieties were taken into consideration. For example secondary check variety Hawkeye yielded 1.126 times as much as primary check variety Richland in 284 yield comparisons. Variety Richland was grown in all Corn Belt tests of maturity group II during the years 1941 to 1957. To calculate relative test yields of varieties grown in later years their test yields (in tests conducted from 1958-60) were divided by those of Hawkeye and then multiplied by 1.126, the relative test yield of Hawkeye, the secondary check variety. In this way test yields of individual varieties were expressed in relative yields of primary check varieties within each maturity group. A further adjustment was made between maturity groups. In Corn Belt tests primary check varieties Earlyana, Richland, Dunfield and Chief yielded 29.1, 26.7 and 27.8 bushels per acre respectively (averaged over all tests and locations). The average yield of variety Richland, grown in 462 Corn Belt tests, was taken as base yield and all relative test yields of varieties grown in other maturity groups were adjusted by the yield ratio of their check varieties relative to variety Richland. Aside from these major deviations from the procedure outlined for the Kansas wheat variety index minor changes were made if necessitated by data restrictions.

Corn Hybrid Index

Computational procedures for corn hybrid indices differed from those of other crop variety indices. The objective in computing corn hybrid indices was to measure annual yield differences between corn hybrids and open-pollinated corn varieties. Corn hybrid indices could have been constructed analogously to other crop variety indices if corn hybrids had been tested together with open-pollinated varieties over the same period of years. However, tests of open-pollinated corn varieties were discontinued in the major corn producing states 10 to 20 years ago. In Iowa, for example, open-pollinated varieties have not been grown in official tests since 1940. Higher yields attained in corn tests after 1940 could not be attributed to improvements in hybrid corn alone. Increased fertilizer application on corn test plots contributed to yield changes over the years. Rapid turnover of new corn hybrids and the fact that many corn hybrids are best adapted to subregions of states added to the problem of constructing reliable corn hybrid indices on state basis.

State corn hybrid indices were estimated according to the following procedure. Available test data - often obtained by contacting research workers engaged in state corn breeding programs - were examined for geographic patterns. In some states corn yield tests were conducted year after year at the same locations. In other states corn test locations shifted frequently over time. Tests conducted in the same crop district and comprising the same or similar hybrids, e.g., tests within the same maturity group, were combined. For each of the regional tests open-pollinated check varieties and check hybrids were selected. Selected check hybrids had been tested at the same location for ten or more years. Testing-periods of successive check hybrids overlapped by four or more years. On the basis of test yields of check hybrids estimates of corn hybrid yields relative to open-pollinated corn yields were made. After relative test yields of the average of all hybrids were computed for each year and each location, they were aggregated according to relative corn acreages of respective crop districts. Acreage weights rather than production weights were attached to regional yield indices because acreage weights were often more stable over time. Usually relative tests yields in lower yielding areas within a state advanced more rapidly over time than in higher yielding areas. Consequently a compensating adjustment may have taken place which reduced the significance of the problem of choice between aggregation by acreage or production weights. After aggregation state corn hybrid indices were estimated by combining annual aggregated relative yield indices with annual adoption rates of hybrid corn.

A hypothetical example may serve as illustration of estimating state corn hybrid indices. It is assumed corn tests are conducted at a location representative of corn yield conditions of a crop district within a state. Hypothetical average yields of all corn hybrids are listed in column 2 of Table 3.4 and average yields of open-pollinated corn varieties (O-P) are listed in column 3 by years. Relative yield ratios of corn hybrids over open-pollinated corn are computed by dividing annual entries of column 2 by corresponding entries of column 3. It is assumed that yield tests of open-pollinated corn are discontinued after 1940 and that average yields of all entries continue to rise over time. Average yields of all entries need not advance at a constant rate, the same procedures would apply if average yields increased at a diminishing rate. It is assumed that this continuous yield increase is due to gradual replacement of older by newer corn hybrids as well as higher rates of fertilizer application and other improvements in cultural practices.

In the hypothetical example open-pollinated corn varieties are not grown in yield tests after 1940. Yields of open-pollinated corn varieties are estimated by relative yields of successive check Hybrids 1, 2, 3, 4 in Table 3.4 and Figure 3.1. Yields of check hybrids are tabulated in columns 4 to 7 of Table 3.4 and depicted in Figure 3.1 as curves intersecting the average yield line of all corn hybrids. Hybrid 1 yields 1.150 times as much as open-pollinated varieties over comparative test years 1935 to 1940. Hybrid 2 yields 1.087 times as much as Hybrid 1 from 1940 to 1945, Hybrid 3 1.080 times as much as Hybrid 2 and Hybrid 4 1.074 times as much as Hybrid 3. Since Hybrid 2 yields 1.087 times as much

Table 3.4. Hypothetical state corn hybrid index

Year	Hypothetical Corn Test Yields in Bushels: Average of All Hybrids	Average of O-P Var.	Hybrid 1	Hybrid 2	Hybrid 3	Hybrid 4	Relative Hybrid Corn Test Yields	Adoption Rate of Hybrid Corn	State Corn Hybrid Index
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1930	50.0	50.0					1.00	.00	1.00
1931	51.7	51.0					1.01	.00	1.00
1932	53.3	51.9					1.03	.00	1.00
1933	55.0	52.7					1.04	.01	1.00
1934	56.7	53.5					1.06	.02	1.00
1935	58.3	54.4	62.6				1.07	.04	1.00
1936	60.0	55.1	63.4				1.09	.10	1.01
1937	61.7	55.8	64.2				1.11	.25	1.03
1938	63.3	56.5	65.0				1.12	.48	1.06
1939	65.0	57.2	65.8				1.14	.66	1.09
1940	66.7	57.9	66.6	72.4			1.15	.78	1.12
1941	68.3	58.6+	67.4	73.2			1.17	.87	1.15
1942	70.0	59.3+	68.2	74.1			1.18	.93	1.17
1943	71.7	59.9+	68.9	74.9			1.20	.96	1.19
1944	73.3	60.5+	69.6	75.6			1.21	.98	1.21
1945	75.0	61.1+	70.3	76.4	82.5		1.23	.98	1.23
1946	76.7	61.7+		77.1	83.3		1.24	.99	1.24
1947	78.3	62.2+		77.8	84.0		1.26	.99	1.26
1948	80.0	62.7+		78.4	84.6		1.28	1.00	1.28
1949	81.7	63.2+		79.0	85.3		1.29	1.00	1.29

+Estimated by yield comparisons between open-pollinated corn varieties and check hybrids 1, 2, 3, 4.

Table 3.4 (Continued)

Year	Hypothetical Corn Test Yields in bu. Average of All Hybrids	Average of O-P Var.	Hybrid 1	Hybrid 2	Hybrid 3	Hybrid 4	Relative Hybrid Corn Test Yields	Adoption Rate of Hybrid Corn	State Corn Hybrid Index
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1950	83.4	63.7^{+}		79.6	86.0	92.4	1.31	1.00	1.31
1951	85.0	64.1^{+}			86.5	92.9	1.33	1.00	1.33
1952	86.7	64.5^{+}			87.1	93.5	1.34	1.00	1.34
1953	88.3	64.9^{+}			87.6	94.1	1.36	1.00	1.36
1954	90.0	65.2^{+}			88.0	94.5	1.38	1.00	1.38
1955	91.6	65.5^{+}			88.4	95.5	1.40	1.00	1.40
1956	93.3	65.8^{+}			88.8	95.4	1.42	1.00	1.42
1957	95.0	66.0^{+}			89.1	95.7	1.44	1.00	1.44
1958	96.7	66.2^{+}			89.4	96.0	1.46	1.00	1.46
1959	98.3	66.4^{+}			89.6	96.3	1.48	1.00	1.48
1960	100.0	66.6^{+}			89.9	96.6	1.50	1.00	1.50
Estimated yield ratios of successive check hybrids:			Hybr.1 / O-P 1.150	Hybr. 2 / Hybr. 1 1.087	Hybr.3 / Hybr. 2 1.080	Hybr.4 / Hybr. 3 1.074			
Estimated yield ratios of check hybrids and O-P corn:			Hybr. 1 / O-P 1.15	Hybr. 2 / O-P 1.25	Hybr. 3 / O-P 1.35	Hybr. 4 / O-P 1.45			

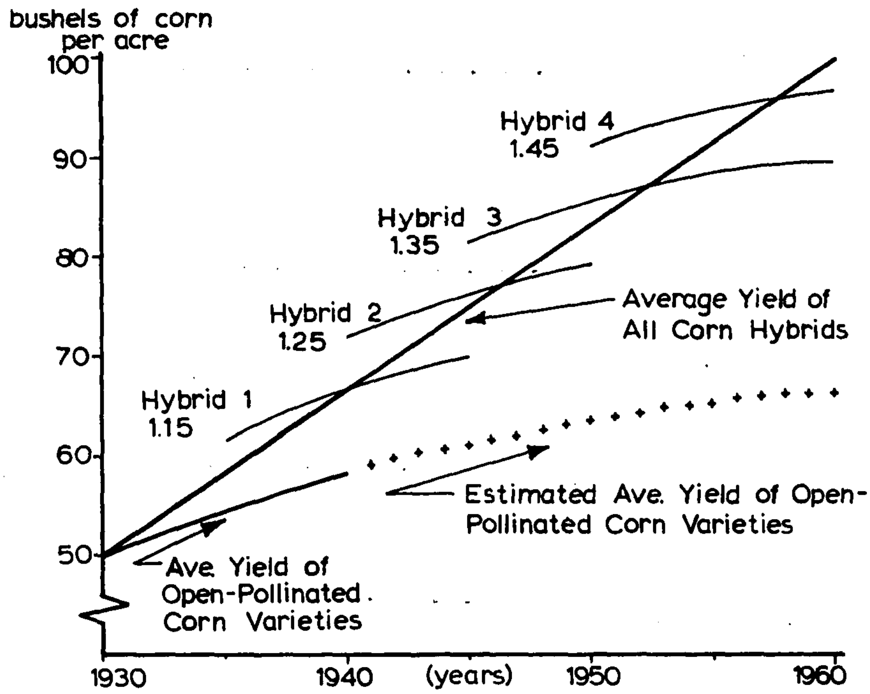


Figure 3.1. Hypothetical example of estimation of annual yields of open-pollinated corn varieties

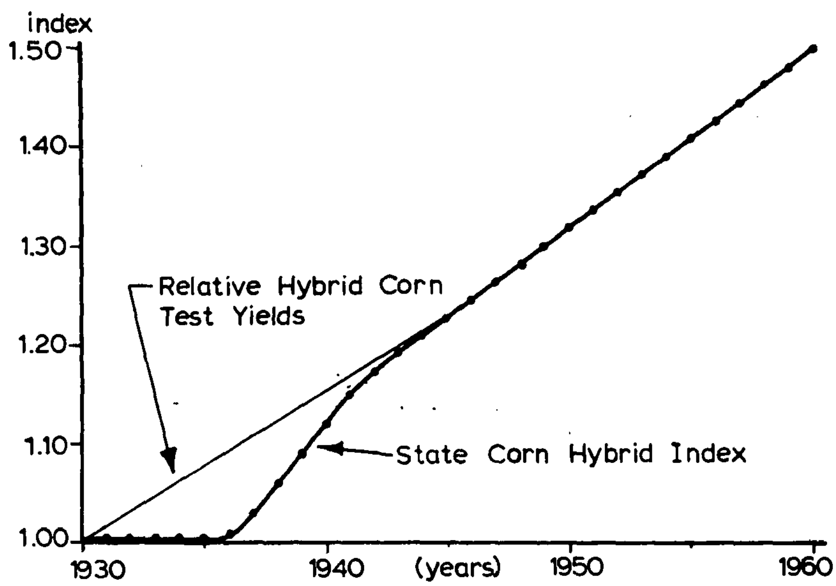


Figure 3.2. Hypothetical state corn hybrid index, 1930 to 1960

as Hybrid 1 it is estimated to yield 1.25 (i.e., 1.150 x 1.087) times as much as open-pollinated varieties. Correspondingly Hybrids 3 and 4 are estimated to yield 1.35 (i.e., 1.25 x 1.080) and 1.45 (i.e., 1.35 x 1.074) times as much as open-pollinated varieties. By this procedure yields of open-pollinated varieties are computed by yields of check Hybrids 1 to 4. For computation of annual relative test yields of the average of all hybrid entries after 1940 annual average yields of all corn hybrids are divided by estimated yields of open-pollinated corn. Relative test yields of corn hybrids are shown in column 8 of Table 3.4 and represented by the thin line in Figure 3.2.

If all corn acreage of the hypothetical state is located in the crop district analyzed, a state corn hybrid index can be derived by multiplying annual relative test yields with annual adoption rates of hybrid corn and adding the proportion of the corn acreage not planted to hybrid corn (multiplied by 1.00, the relative test yield of open-pollinated corn). For example in 1940 the state corn hybrid index is (1.15 · .78) + (1.00 · .22) = 1.12 and from 1948 on, annual state corn hybrid indices equal annual relative corn hybrid test yields because by that time hybrid corn is completely adopted (Table 3.4, column 10). Comparison between lines of relative test yields and state corn hybrid indices in Figure 3.2 illustrates that annual indices remain constant at 1.00 prior to adoption, rise more rapidly than relative test yields during adoption and advance at the same rate after adoption. According to Figure 3.2 and corresponding values in column 10 of Table 3.4 the value of the state corn hybrid index is 1.00 in 1930, advances to 1.11 by 1940, 1.31

by 1950 and reaches 1.50 by 1960. In this hypothetical example adoption and further improvement of hybrid corn raises yields by 50 percent between the years 1930 and 1960. Over the same time period corn test yields increase from 50 to 100 bushels, reflecting a 100 percent yield increase. Removing the assumption that all corn of the hypothetical state is grown in one crop district does not essentially alter the procedure. If several crop districts are involved relative test yields are aggregated before the rate of adoption is incorporated in the state corn hybrid index.

In contrast to the hypothetical example empirical analysis subjects derivation of annual state corn hybrid indices to errors of estimation. By taking excerpts from empirical analysis the applicability of the outlined procedures can be demonstrated. In Table 3.5 data are tabulated which were used for computation of relative corn hybrid test yields of Corn Test District 8 in Iowa. Data arrangement in Table 3.5 conforms to that of Table 3.4. Years, average test yields of all corn hybrids, actual and estimated average yields of open-pollinated corn varieties are entered in the first three columns of the table as before. Corn yield test results of five check hybrids are listed in columns 4 to 8 and estimates of relative hybrid corn yields are tabulated in column 9. Iowa Hybrid 939, Maygold 49, Ohio C 92, Iowa Hybrid 4527 and Iowa Hybrid 4517 were used as check hybrids in succession. Average yield ratios between check hybrids and estimated yield ratios between check hybrids and open-pollinated varieties were used to compute relative corn hybrid yields annually. All computations follow the pattern outlined before. For example the relative yield 1.111 of check hybrid Maygold 59 was computed

Table 3.5. Relative corn test yields and related data of yield tests conducted in corn test district 8, Iowa, 1930 to 1960[a]

Year	Corn Test Yields in Bushels: Average of All Hybrids	Average of O-P Var.	Iowa Hybrid 939	Maygold 49	Ohio C 92	Iowa Hybrid 4527	Iowa Hybrid 4517	Relative Hybrid Corn Test Yields
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1930	47.3	37.2						1.272
1931	57.9	52.6						1.101
1932	71.2	63.8						1.116
1933	65.8	58.2						1.131
1934	29.9	20.0						1.495
1935	68.7	60.7	70.3					1.122
1936	37.2	30.0	37.9					1.178
1937	79.2	72.8	79.9					1.108
1938	75.9	68.3	75.1					1.130
1939	81.3	72.9	80.3					1.134
1940	76.8	66.3	73.3	77.8				1.199
1941	80.8	60.8+	67.3	78.9				1.330
1942	92.8	75.3+	84.1	97.1				1.232
1943	84.7	68.0+	81.7	81.7				1.245
1944	79.6	64.4+	76.6	77.2	87.6			1.236
1945	86.7	72.8+	91.2	88.6	92.9			1.191
1946	75.3	59.9+	69.0	80.3	75.3			1.257
1947	49.0	37.6+	36.2	49.3	59.1			1.303
1948	97.4	75.7+	87.0	96.5	99.8			1.287
1949	67.9	51.0+		63.4	67.2	72.6		1.332

[a]Source: References; Corn, Iowa.

+Estimated by yield comparisons between open-pollinated corn varieties and five check hybrids.

Table 3.5 (Continued)

Year	Corn Test Yields in Bushels: Average of All Hybrids	Average of O-P Var.	Iowa Hybrid 939	Maygold 49	Ohio C 92	Iowa Hybrid 4527	Iowa Hybrid 4517	Relative Hybrid Corn Test Yields
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1950	90.2	68.4^{+}		90.2	92.2	90.1		1.318
1951	59.7	46.2^{+}		54.6	60.0	70.6		1.293
1952	104.0	81.6^{+}		107.2	109.3	108.2		1.275
1953	96.2	75.9^{+}		99.5	102.8	99.8		1.268
1954	98.5	75.5^{+}		101.0	111.8	97.8	97.8	1.305
1955	108.1	84.8^{+}			109.0	116.0	106.0	1.275
1956	104.5	78.4^{+}			108.0	108.0	97.2	1.333
1957	136.6	102.3^{+}			137.0	144.0	95.8	1.335
1958	114.6	85.4^{+}				114.0	106.1	1.342
1959	125.6	96.6^{+}				137.0	94.2	1.300
1960	102.5	96.6^{+}				98.0	106.1	1.397

Estimated Yield ratios of Successive check hybrids:	$\frac{\text{Ia 939}}{\text{O-P}}$ 1.138	$\frac{\text{MG 49}}{\text{Ia 939}}$ 1.111	$\frac{\text{Oh C92}}{\text{MG 49}}$ 1.063	$\frac{\text{Ia 4527}}{\text{Oh C92}}$ 1.021	$\frac{\text{Ia 4517}}{\text{Ia 4527}}$ 1.005
Estimated Yield ratios of Check hybrids and O-P corn:	$\frac{\text{Ia 939}}{\text{O-P}}$ 1.138	$\frac{\text{MG 49}}{\text{O-P}}$ 1.264	$\frac{\text{Oh C92}}{\text{O-P}}$ 1.344	$\frac{\text{Ia 4527}}{\text{O-P}}$ 1.372	$\frac{\text{Ia4517}}{\text{O-P}}$ 1.379

by averaging annual yield ratios of Maygold 59 and Iowa Hybrid 939 over the years 1940 to 1948. On the basis of this ratio the relative yield between Maygold 59 and open-pollinated varieties was estimated at 1.138 x 1.111 = 1.264 as shown in column 4 of Table 3.5. The relative hybrid corn test yield for the year 1949, for example, was estimated by check hybrid Maygold as (67.9 / (63.4 / 1.264)) = 1.354 and by check hybrids Ohio C92 and Iowa Hybrid 4527 as 1.358 and 1.283 respectively. By averaging these three estimates the 1948 relative corn hybrid test yield of 1.332 was obtained. According to this test yield value all hybrid entries yielded on the average 1.332 times as much as open-pollinated varieties or 67.9 compared to 51.0 bushels. Noticeable differences between hypothetical data in Table 3.4 and empirical data in Table 3.5 are annual yield variations as well as fluctuations in relative corn test yields. However, ten additional data sets were used to compute relative corn hybrid test yields for Iowa and consequently the magnitude of year to year variations in relative corn test yields was reduced.

Relative corn test yields of Iowa were aggregated over 11 corn test districts and are represented by plot diagram in Figure 3.3. A linear regression line was fitted regressing aggregate <u>relative</u> corn hybrid test yields on years. The linear regression line implies that relative corn hybrid yields advanced at a constant rate. It may be suggested that the rate of advance is more likely to diminish over time and fitting a curvilinear function would be more appropriate as it would allow for diminishing returns to further efforts in corn breeding. This proposition would hold true if research inputs in corn hybrid improvements had remained constant over time. Today corn testing programs in almost all states are more intensive than 20 years ago, the number of test locations is greater and more hybrids are tested at each location. A constant rate of advance in corn hybrid yield improvement may well have been achieved by this intensified research. Consequently linearity of the regression line of relative corn hybrid yields does not refute the hypothesis of diminishing returns to additional research inputs.

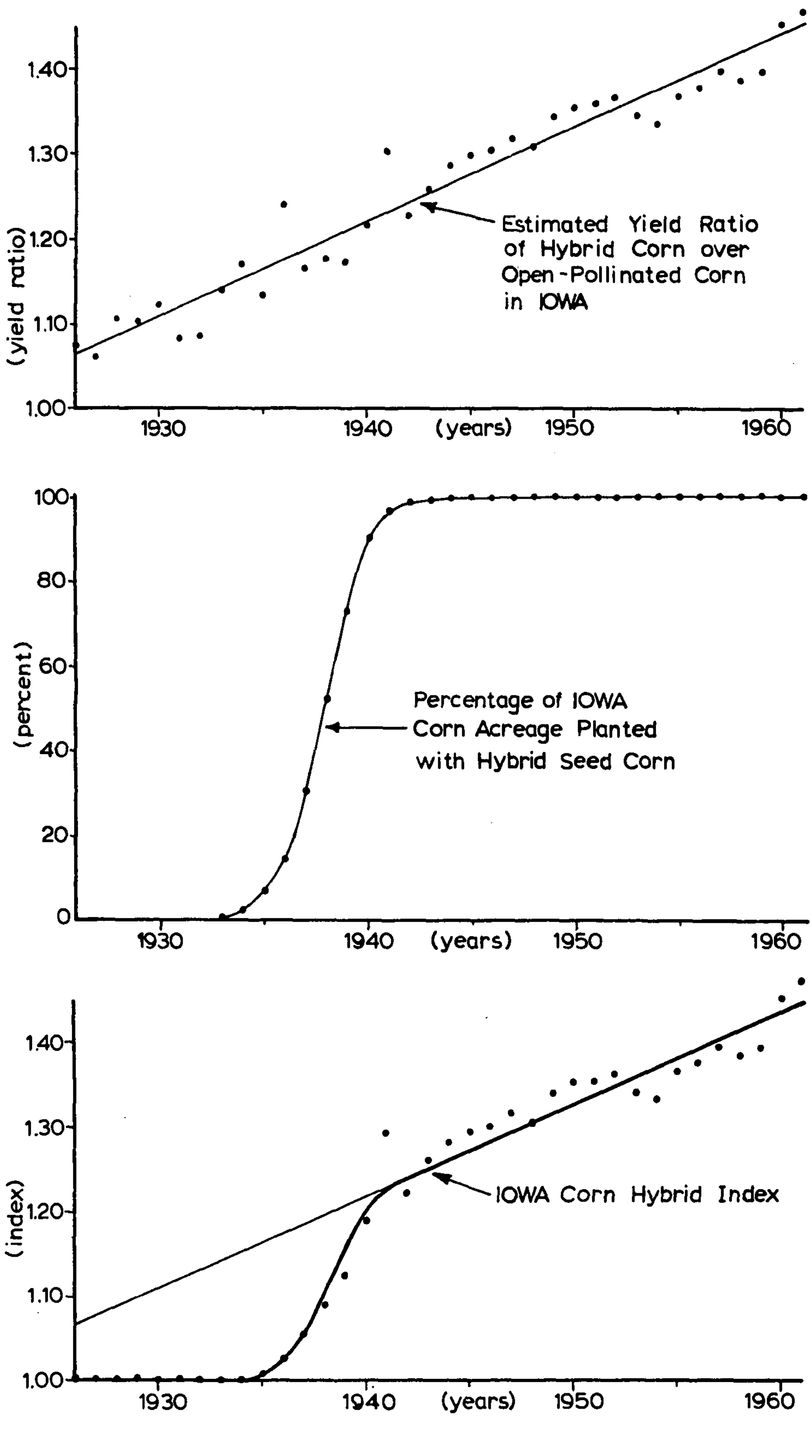
Estimates of state corn acreage planted with hybrid seed corn are published annually in Agricultural Statistics. The adoption rate of hybrid corn in Iowa is pictured in Figure 3.4. As may be expected the curve representing relative Iowa corn hybrid acreage approaches the shape of a logistic growth function. In Iowa, corn hybrids were first grown in 1933, by 1938 about one half of the corn acreage was planted to hybrid corn and by 1943 it occupied 99.5 percent of the corn acreage. As an example of the computation of the Iowa corn hybrid index the year 1939 may serve. In 1939, 73.4 percent of Iowa's corn acreage was planted to corn hybrids. At that time the estimated relative corn hybrid yield ratio was approximately 1.21, therefore the Iowa corn hybrid index for 1939 was $(.734) \cdot (1.21) + (.266 \cdot 1.00) = 1.154$. As illustrated in Figure 3.5 the Iowa corn hybrid index remained nearly constant at 1.00 during the early thirties, increased rapidly during the time of adoption, leveled off to the rate of change of relative corn hybrid yields during the early forties and exceeded the 1.40 value before 1960. This estimate implies that since the first adoption of hybrid corn Iowa corn yields have been increased by more than 40 percent due to hybridization and continuous development of newer and higher yielding corn hybrids.

The reliability of these state corn hybrid indices depends on several factors. The more important ones are: (1) amount of relevant data employed in constructing corn hybrid indices, (2) accuracy of yield estimates of open-pollinated corn varieties and (3) amount of error introduced by using results of corn yield tests conducted by agricultural experiment stations. An attempt was made to obtain adequate information on corn test yield results of individual states. Usually the more important corn producing states conducted a more intensive testing program than other states. Numbers of testing regions, relative yields of check hybrids and other data, essential for the construction of state corn hybrid indices are tabulated in Appendix B. It was estimated that yields of at least 60,000 corn hybrid test entries were used for index computations. Accuracy of yield estimates of open-pollinated corn was difficult to test because whenever yield estimates of open-pollinated corn varieties were made, actual test yield results of open-pollinated corn varieties were not available. However, some comparisons between yields of hybrids and selected open-pollinated varieties were made on corn yield test plots in southern Minnesota during 1960. For computation of changes in relative test yields a regression equation was fitted and the yield ratio between hybrids and open-pollinated corn was estimated at 1.58 in 1960. The 1960 average yield of 53 hybrid entries at 3 locations was 108.0 bushels. Therefore the estimated yield of open-pollinated varieties in the Southern Zone was 108.0 / 1.58 or 68.4 bushels. Actual yield of the open-pollinate variety (Murdock), tested at 3 locations in the Southern Zone, was 66 bushels. Estimated and actual yields were very close. This result

Figure 3.3. Estimated relative corn hybrid test yields, Iowa, 1926 to 1961

Figure 3.4. Adoption of hybrid corn, Iowa, 1926 to 1961

Figure 3.5. Estimated corn hybrid index, Iowa, 1926 to 1961



1.40
1.30
1.20
1.10
1.00
(yield ratio)
1930
1940
(years)
1950
1960
Estimated Yield Ratio of Hybrid Corn over Open-Pollinated Corn in IOWA
100
80
60
40
20
0
(percent)
1930
1940
(years)
1950
1960
Percentage of IOWA Corn Acreage Planted with Hybrid Seed Corn
1.40
1.30
1.20
1.10
1.00
(index)
1930
1940
(years)
1950
1960
IOWA Corn Hybrid Index

supports the methodology but additional testing of the procedure would be desirable.

As a third factor the error introduced by using experimental data was mentioned. Values of annual average yields of all hybrid entries in experimental yield tests were used for the computation of relative corn yields of each testing district. Many of the hybrid entries were experimental hybrids. In as far as newly developed hybrids might be quite superior in yielding ability to hybrids commonly grown by farmers, relative corn hybrid yields and consequently state corn hybrid indices might have overestimated the yielding ability of hybrids grown by farmers. Again, evidence to test this hypothesis extensively was not available. In May 1952 the Iowa Agricultural Experiment Station in cooperation with the Iowa Crop and Livestock Reporting Service conducted a survey on acreage distribution of commonly grown corn hybrids (24, p. 6). By mail 12,000 questionnaires were sent to Iowa farmers asking them to list their acreage planted to each hybrid. On the basis of this information 26 different hybrids, widely grown in Iowa, were selected and entered in the 1953 Iowa corn yield tests. At each test location 10 of the commonly grown hybrids were planted together with test entries. Results of these tests are presented in Table 3.6. Average test yields of 10 widely grown hybrids are listed in column 3, average test yields of 71 other hybrids and averages of all entries are listed in columns 5 and 7 for each of the 12 corn testing districts. Evidently yields of both groups were very similar as evidenced by yield comparisons in column 8. Overall averages of test yields was almost identical but slightly in favor of hybrids

Table 3.6. Comparisons between average corn test yields and yields of widely grown hybrids in 12 corn testing districts, Iowa, 1953[a]

Corn Test District	Number of Entries and Test Yields: Widely Grown Hybrids No.	Widely Grown Hybrids Yield in Bu.	Other Hybrids No.	Other Hybrids Yield in Bu.	All Hybrids No.	All Hybrids Yield in Bu.	Yield Comparisons: Widely Grown Hybrids / Other Hybrids
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=(3)/(5)
1	10	102.5	71	101.6	81	101.7	1.009
2	10	84.3	71	82.5	81	82.7	1.022
3	10	107.4	71	109.3	81	109.1	.983
4	10	113.7	71	113.9	81	113.9	.998
5	10	104.8	71	104.7	81	104.7	1.001
6	10	74.8	71	77.3	81	77.0	.968
7	10	88.9	71	88.3	81	88.4	1.009
9	10	85.4	71	82.5	81	96.2	.987
10	10	97.7	71	96.2	81	96.4	1.016
11	10	115.3	71	115.9	81	115.8	.995
12	10	83.9	71	81.8	81	82.1	1.026
Average	10	96.2	71	95.9	81	95.9	1.004

[a]Source: (24).

grown by Iowa farmers. Therefore it was assumed that the rate of advance in relative corn hybrid yields due to genetic improvements was the same for hybrids grown on farms as for hybrids grown in experimental station tests. Corn hybrid indices of other states and related data are listed in Appendix B.

Fertilizer Application

In the U.S. fertilizer consumption has more than doubled since World War II, from 2.64 million tons in 1945 to 7.35 million tons of plant nutrients in 1960 (25, p. 71). To measure the impact of increased fertilizer application of state crop yields it was necessary to estimate annual rates of fertilizer application by crops and by states. Estimates were made on the basis of data published by the National Fertilizer Association for the years 1927, 1938 and 1944 (26, 27, 28), estimates for the years 1950, 1954, and 1959 (29, 30, 31) were obtained from the U.S. Department of Agriculture. In addition U.S.D.A. estimates of total annual plant nutrient consumption by states covering the years 1930 to 1961, were used (25, 32, 33).

Estimation of annual application rates of plant nutrients by states and crops proceeded in three steps. First, U.S.D.A. estimates of N (Nitrogen), P (Phosphoric Oxide) and K (Potash) crop application rates for the years 1950, 1954 and 1959 were adjusted to conform to total state consumption data for the same years. Similar adjustments were made on data of the National Fertilizer Association for the earlier years 1944, 1938 and 1927. Second, total consumption of plant nutrients was reduced to estimated consumption levels of <u>major</u> crops. Third, N-P-K application rates were estimated by crops and states for each year covering the years 1927 to 1961.

Computation of Indiana fertilizer rates by nutrients, crops and years may illustrate estimation procedures. In Table 3.7 data on estimated use of N-P-K plant nutrients are presented for the years 1950, 1954 and 1959 by major crops. Adjusted N-P-K quantities are posted in columns 1, 3, 5 and 7. Quantities used on major crops and other crops add up to Total 1 in each year. Nutrient quantities of Total 1 represent tonnages of total nutrient use estimated annually by the U.S.D.A; they were taken as best estimates of annual state nutrient consumption. All other estimates were adjusted to conform to these standard estimates. Total 2

Table 3.7. Estimated use of principal plant nutrients and application rates per acre by crops, Indiana; 1950, 1954 and 1959[a]

Year	Crops	N Total Tons (1)	N Lbs./Acre (2)	P Total Tons (3)	P Lbs./Acre (4)	K Total Tons (5)	K Lbs./Acre (6)	N+P+K Total Tons (7)	N+P+K Lbs./Acre (8)
		Quantities of Plant Nutrients Used[b]							
1950	Corn	13859	6.33	43672	19.94	42184	19.26	99715	45.53
	Wheat	7346	9.58	23630	30.83	14906	19.45	45882	59.86
	Oats	2096	3.29	9244	14.54	6378	10.03	17718	27.86
	Soybeans	829	1.00	7617	9.22	8408	10.18	16854	20.40
	Tame Hay	178	.19	3278	3.47	1809	1.91	5265	5.57
	Others	2057		9849		7723		19629	
	Total 1	26365		97290		81408		205063	
	Adj. Factor	1.02484		.94193		1.03981			
	Total 2	25726		103288		78291		207305	
1954	Corn	48486	20.06	84047	34.77	94563	39.12	227096	93.95
	Wheat	14855	22.54	20376	30.92	21736	32.98	56967	86.44
	Oats	5876	9.39	17609	28.13	17909	28.61	41394	66.13
	Soybeans	0	0	9533	9.83	10329	10.65	19862	20.48
	Tame Hay	1041	1.17	4975	5.59	4859	5.46	10875	12.22
	Others	4246		11531		13027		28804	
	Total 1	74504		148071		162423		384998	
	Adj. Factor	1.00000		1.00000		1.00000			
	Total 2	74504		148071		162423		384998	
1959	Corn	89597	34.44	105268	40.46	123442	47.45	318307	122.35
	Wheat	18589	30.55	23792	39.10	24855	40.85	67236	110.50
	Oats	5328	12.15	9995	22.79	10133	23.11	25456	58.05
	Soybeans	1323	1.15	12046	10.51	13015	11.36	26384	23.02
	Tame Hay	2714	3.85	3601	5.11	3958	5.61	10273	14.57
	Others	5606		12482		13621		31709	
	Total 1	123157		167184		189024		479365	
	Adj. Factor	1.04042		1.04253		1.03961			
	Total 2	118372		160364		181822		460558	

[a]Source: (25, 29, 30, 31, 33).

[b]Plant nutrients nitrogen, phosphoric oxide and potash are referred to as N, P, K respectively.

Table 3.8. Harvested acres, fertilization practices and average quantities of N-P-K nutrients used on major crops receiving fertilizer, Indiana, 1944

Crop	Harvested Acres (Indiana)	Acres Fertilized[a]				Plant Nutrients used per Fertilized Acre[a]					
						N		P		K	
		At Planting	Top or Side Dressing	At Planting	Top or Side Dressing	At Planting	Top or Side Dressing	At Planting	Top or Side Dressing	At Planting	Top or Side Dressing
	In 1000 (1)	% (2)	% (3)	In 1000 (4)	In 1000 (5)	Lbs. (6)	Lbs. (7)	Lbs. (8)	Lbs. (9)	Lbs. (10)	Lbs. (11)
Corn	4594	94.5	4.6	4341	211	2.3	5.8	16.5	31.1	12.6	15.2
Wheat	1266	93.0	.4	1177	5	3.7	17.1	22.6	16.6	14.8	22.8
Oats	1172	45.2		530		2.2		20.6		11.8	
Hay	1602	4.9		78		4.0		31.0		16.6	
Soybeans	1473	34.2	.1	504	1	1.5		15.2	28.2	14.0	28.2
Sweet Corn	46.8	96.2		45		2.6		15.6		12.5	
Pasture	4751	2.3	1.6	109	76	21.3	3.3	49.5	25.6	21.6	4.8
Rye	86	58.3		50		3.4		21.2		14.3	
Alfalfa	402	37.1	5.5	149	22	1.9	.6	37.9	41.3	27.6	26.9
Tame Hay	2004										

[a]Source: (28, p. 9).

top or side dressing are shown in columns 2 and 3. Corresponding rates of application for both practices are posted in columns 6 to 11. Average use of plant nutrients per harvested acre was computed as follows.[1] Harvested acres in column 1 were multiplied by relative acres in columns 2 and 3 to obtain, after division by 100, acres fertilized. For example according to column 2 in Table 3.8, 94.5 percent of corn, 34.2 percent of soybeans and 2.3 percent of the pasture acreage received fertilizer at planting time. On the basis of these percentages acres receiving fertilizer were computed as shown in columns 4 and 5. Multiplying acreages by application rates (in pounds of primary plant nutrients) and dividing by 2,000 equals unadjusted nutrient tons of each nutrient and in total as shown in columns 1 to 4 in Table 3.9. Actual State tonnage was 91,045 tons compared to unadjusted tonnage of 130,310 tons. Therefore an adjustment factor of .69868 was used to deflate tonnages used on individual crops as in column 5. Adjusted rates of N-P-K application in column 6 were estimated by dividing adjusted N-P-K tons by harvested acres of Table 3.8, column 1. Plant nutrient ratios were computed on the basis of unadjusted nutrient tons and used to obtain preliminary rates of application of individual nutrients as shown in columns 1 to 3 of Table 3.10. For final estimates of N-P-K application preliminary N-P-K rates were multiplied by harvested acres (Table 3.8, column 1) and compared to total standard nutrient tons. Comparison between final and preliminary application rates

[1]It was assumed that all farmers who applied fertilizer followed the same practices as those who were interviewed at the time of the survey and that relative crop acres on these farms equaled relative crop acres of the State.

Table 3.9. Preliminary estimates of plant nutrient use and rates of application per harvested acre, Indiana, 1944[a]

Crop	Unadjusted Nutrient Tons N Tons	P Tons	K Tons	N+P+K Tons	Adjusted Tons of N+P+K Tons	Adj. Rate of Application N+P+K Lbs.
	(1)	(2)	(3)	(4)	(5)	(6)
Corn	5604	39094	28952	73650	51458	22.402
Wheat	2220	13342	8767	24329	16998	26.853
Oats	583	5459	3127	9169	6406	10.932
Hay[b]	156	1209	647	2012	1406	1.755
Soybeans	378	3844	3542	7764	5425	7.366
Sweet Corn	58	351	281	690	482	20.598
Pasture	1286	3671	1360	6317	4414	1.858
Rye	85	530	358	973	680	15.814
Alfalfa[b]	148	3278	1980	5406	3777	18.791
Tame Hay	304	4487	2627	7418	5183	5.173
Unadjusted Total				130310		
Adjusted Total					91045[c]	

[a]Computed from data of Table 3.8, herein.

[b]Included under tame hay but excluded from total to avoid duplication.

[c]Only fertilizer application to major crops was considered therefore the standard tonnage was adjusted by factor .937 from 97,167 to 91,045 tons.

Table 3.10. Preliminary and final estimates of N-P-K application per crop acre, Indiana, 1944

Crop	Estimates of N-P-K Application per Acre in Pounds[a] Preliminary N	P	K	N+P+K	Final N	P	K	N+P+K
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Corn	1.70	11.89	8.81	22.40	1.91	11.98	8.52	22.41
Wheat	2.45	14.72	9.68	26.85	2.75	14.85	9.37	26.95
Oats	.70	6.50	3.73	10.93	.78	6.56	3.61	10.95
Hay	.14	1.06	.56	1.76				
Soybeans	.36	3.65	3.36	7.37	.40	3.66	3.25	7.33
Sweet Corn	1.73	10.48	8.39	20.60				
Pasture	.38	1.08	.40	1.86				
Rye	1.38	8.61	5.82	15.81				
Alfalfa	.51	11.38	6.88	18.79				
Tame Hay	.21	3.13	1.83	5.17	.24	3.15	1.77	5.16

[a]Computed from data of Table 3.9.

of Table 3.10 shows that this adjustment was small. It implies that nutrient ratios as estimated by the National Fertilizer Association checked closely with nutrient ratios of total standard tonnages. Following the same procedure analysis of other states showed similar results.

Estimation of fertilizer application in earlier years was based on results of the first and second fertilizer surveys of the National Fertilizer Association (26, 27). Procedures of analysis were practically the same for both surveys and it may suffice to illustrate the general method by describing the 1938 estimation. During the course of the 1938 survey interview reports of 32,148 farmers were collected and analyzed. The survey "was made largely among fertilizer users, and to a certain extent among the larger and more successful users" (27, p. 3). Therefore adjustments were made here to more nearly represent average practices. Estimates of nutrient use were computed on the basis of survey data shown in columns 1 to 3 of Table 3.11. Estimates in column 4 were then adjusted (by a factor of 1.06967) to check with total standard nutrient tons of column 5 of the same table. The adjustment amounted to approximately 7 percent. Plant nutrient ratios were also estimated on the basis of information collected by the National Fertilizer Association. Predominant analyses of fertilizers used by farmers interviewed during the survey and weighted average nutrient ratios are shown in Table 3.12. These nutrient ratios were used for computation of preliminary rates of fertilizer application shown in Table 3.13. Preliminary rates were calculated by dividing adjusted nutrient use by standard harvested acres (columns 5 and 6 of Table 3.11) and allocation of N-P-K application

Table 3.11. Estimates of fertilizer and total nutrient use by crops in Indiana, 1938

Crops	Fertilizer Use: Quantity[a] Tons	Quantity[a] %	Ave. Analysis[b] %	Nutrient Use: Unadjusted Tons	Adjusted Tons	Standard Harvested Acres In 1000
	(1)	(2)	(3)	(4)	(5)	(6)
Corn	98000	44.3	22.0	21560	23062	4182
Potatoes	4000	1.8	27.2	1088	1164	53
Wheat	93000	42.1	21.1	19623	20990	1769
Oats	5000	2.3	19.9	995	1064	1310
Onions	300	0.1	28.3	85	91	
Tomatoes	7000	3.2	23.7	1659	1775	
Alfalfa	5000	2.3	26.9	1345	1439	
Others	8700	3.9	21.6[c]	1881	2012	
Unadjusted Total	221000	100.0		48236		
Adjusted Total					51597	

[a]Source: (27, p. 65).

[b]Source: (27, p. 90).

[c]Computed on basis of weighted average nutrient content of fertilizer applied to specified crops.

according to nutrient ratios in Table 3.12. To obtain final estimates of N-P-K application preliminary N-P-K rates were multiplied by harvested acres and compared to total standard nutrient tons. Again adjustments between preliminary and final estimates of nutrient ratios were small, an indication of close correspondence between survey estimates for individual crops by the National Fertilizer Association and U.S.D.A. standard estimates of annual State nutrient consumption.

Final estimates of Indiana application rates of primary plant nutrients to individual crops in Indiana are summarized in Table 3.14 for each survey year. Application rates shown in this table do not account for total consumption of principal plant nutrients. If the rates are

Table 3.12. Predominant nutrient analyses of fertilizer applied to corn, wheat and oats in Indiana, 1938[a]

Crops	Nutrient Analysis N %	P %	K %	Number of Times Used
Corn	0	8	24	38
	0	10	10	39
	0	12	12	101
	0	14	6	35
	0	20	19	19
	0	20	20	16
	1	11	5	13
	2	8	16	18
	2	12	2	26
	2	12	6	438
	3	10	6	23
	3	12	12	12
Weighted Average	6.454	55.618	37.928	
Wheat	0	12	12	12
	0	14	6	22
	0	20	20	39
	1	11	5	14
	2	8	6	19
	2	12	2	17
	2	12	6	493
	3	8	6	13
	4	24	12	25
Weighted Average	9.035	62.389	28.576	
Oats	2	12	6	59
Weighted Average	10.000	60.000	30.000	

[a]Source: (27, pp. 54, 55).

multiplied by harvested acres they account for 92.0 percent of total N-P-K consumption in 1927, 91.3 percent in 1938, 88.0 percent in 1944, 90.4 percent in 1950, 92.66 percent in 1954 and 93.4 percent in 1959. These percentage estimates were made on the basis of adjusted survey estimates which included fertilizer consumption of other crops. Over time these percentage estimates varied less than corresponding estimates of

Table 3.13. Preliminary and final estimates of N-P-K application per crop acre, Indiana, 1938

Crop	Estimates of N-P-K Application per Acre in Pounds							
	Preliminary				Final			
	N	P	K	N+P+K	N	P	K	N+P+K
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Corn	.71	6.12	4.18	11.01	.71	5.95	4.41	11.07
Wheat	2.14	14.80	6.78	23.72	2.13	14.36	7.15	23.64
Oats	.16	.98	.49	1.63	.16	.95	.52	1.63
Tame Hay[a]	.08	1.22	.71	2.01	.08	1.18	.75	2.01

[a]N-P-K ratio of 1944 was used for computation of preliminary estimates.

nutrient consumption of individual crops. For estimation of nutrient consumption in intervening years linear interpolations of these overall percentages were used as restrictions on total plant nutrient consumption. From the year 1945 on percentage restrictions were imposed on total consumption of each nutrient.

For derivation of estimates of annual fertilizer application long and short run changes were taken into consideration. As is evident from estimates in Table 3.14 fertilizer application of five major crops in Indiana has increased manifold since 1927. Relative rates of fertilizer application have changed significantly over time. Long run changes in crop acreages caused changes in the relative consumption of individual crops. Superimposed on these long run trends are short run fluctuations which may have been caused by fluctuations in farm income, acreage adjustments and weather conditions. In view of the existence of long and short run changes, estimation of annual fertilizer consumption by linear interpolation between successive survey years was considered unproductive of realistic estimates. For estimation of annual consumption rates restrictions of state nutrient consumption, changes in rates of nutrient application, relative use of N-P-K nutrients and annual changes in harvested acreage of each of the major crops were taken into account. Preliminary estimates of annual rates of application were made by using (linearly) interpolated values between survey years of N-P-K application rates of individual crops and overall percentage restrictions of state nutrient consumption. After multiplying preliminary application rates of major crops by their annual acreage, total consumption of each nutrient was compared against restricted state nutrient consumption. If they did not equal, all rates were adjusted proportionately. Adjusting preliminary application rates of individual nutrients did not alter rates of all crops uniformly over time because the underlying time trends did still exert their influence.

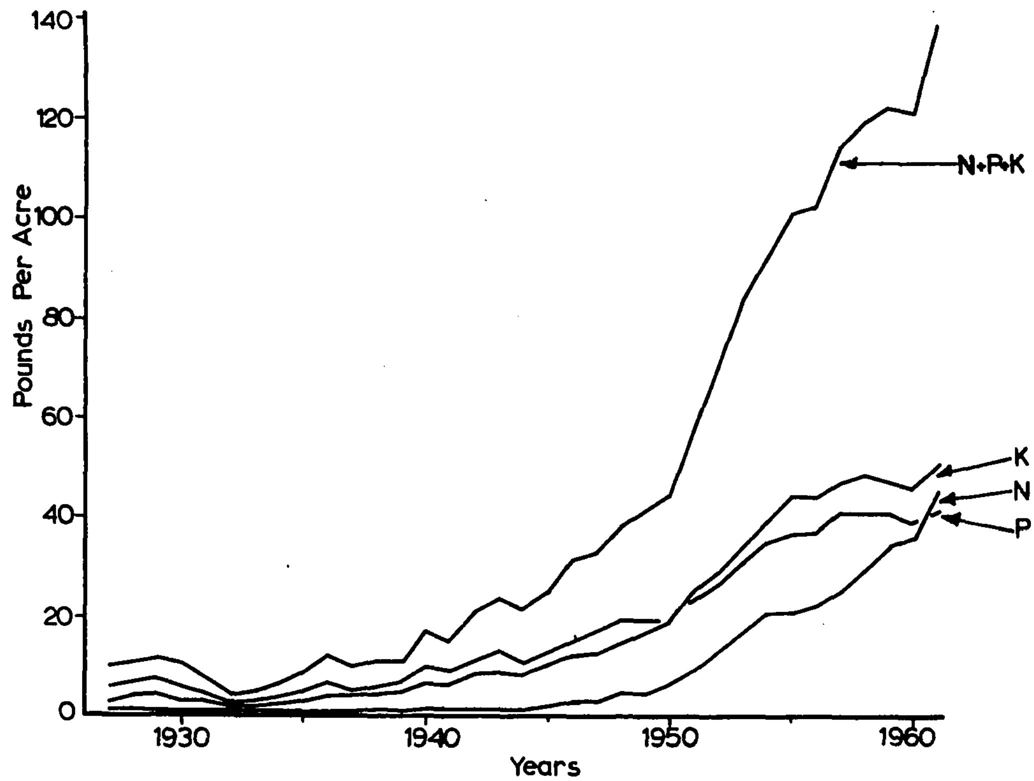
Annual estimates of fertilizer application to Indiana crops are shown in Figures 3.6 and 3.7. In Figure 3.6 annual N-P-K application rates are shown for each nutrient and combined nutrients per acre of corn for the years 1927 to 1961. As illustrated in Figure 3.6 fertilizer application to corn decreased during the early thirties, then gradually increased during the forties and rose rapidly after World War II. Application rates of individual nutrients followed a somewhat similar pattern, but their relative relationships changed over time. Prior to 1940 use of nitrogen was insignificant. Nitrogen application rates increased gradually during the forties but picked up strongly after 1949. According to these

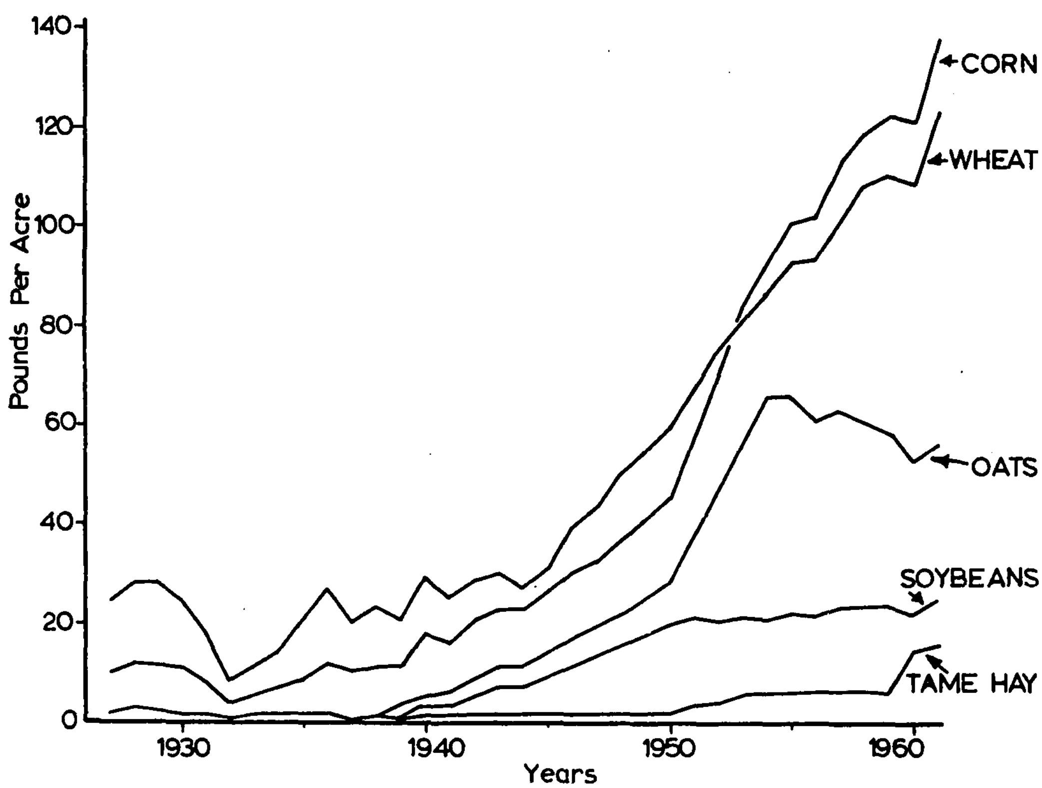
Table 3.14. Summary of estimated application rates per acre of specified crops in pounds of principal plant nutrients in Indiana for the years 1927, 1938, 1944, 1950, 1954 and 1959

Year	Crop	Nutrient rates applied to specified crops			
		N	P	K	N+P+K
		(1)	(2)	(3)	(4)
1927	Corn	.864	5.772	3.614	10.250
	Wheat	2.331	16.494	6.408	25.233
	Oats	.182	1.299	.508	1.989
	Soybeans	.000	.000	.000	.000
	Tame Hay	.080	1.016	1.192	2.288
1938	Corn	.708	5.950	4.410	11.068
	Wheat	2.134	14.365	7.154	23.653
	Oats	.160	.951	.517	1.627
	Soybeans	.000	.000	.000	.000
	Tame Hay	.080	1.184	.749	2.013
1944	Corn	1.906	11.975	8.524	22.405
	Wheat	2.746	14.835	9.366	26.947
	Oats	.785	6.557	3.609	10.951
	Soybeans	.404	3.676	3.251	7.331
	Tame Hay	.235	3.152	1.771	5.158
1950	Corn	6.330	19.945	19.237	45.512
	Wheat	9.579	30.838	19.427	59.844
	Oats	3.300	14.544	10.018	27.862
	Soybeans	1.000	9.222	10.168	20.390
	Tame Hay	.190	3.471	1.908	5.569
1954	Corn	20.060	34.806	39.133	93.998
	Wheat	22.540	30.952	32.991	86.483
	Oats	9.390	28.159	28.619	66.168
	Soybeans	..000	9.840	10.653	20.493
	Tame Hay	1.170	5.596	5.462	12.228
1959	Corn	34.460	40.492	47.452	122.405
	Wheat	30.568	39.131	40.852	110.551
	Oats	12.157	22.808	23.111	58.076
	Soybeans	1.151	10.518	11.361	23.029
	Tame Hay	3.852	5.114	5.610	14.576

Figure 3.6. Estimated annual N-P-K application per acre of corn, Indiana, 1927 to 1961

Figure 3.7. Estimated annual nutrient application per acre of major crops, Indiana, 1927 to 1961


Pounds Per Acre
140
120
100
80
60
40
20
0
1930
1940
1950
1960
Years
N+P+K
K
N
P


Pounds Per Acre
140
120
100
80
60
40
20
0
1930
1940
1950
1960
Years
CORN
WHEAT
OATS
SOYBEANS
TAME HAY

estimates application of nitrogen was more than seven times as heavy in 1959 as it was in 1949, it rose from an estimated 4.5 pounds in 1949 to 34.4 pounds in 1959. Over the same years P and K consumption increased less rapidly. In Figure 3.7 fertilizer application to corn, wheat, oats, soybeans and tame hay is shown in pounds of nutrients per acre. Application rates of all crops increased during the post-war years but relationships of rates changed among crops. Prior to 1953 wheat was the most heavily fertilized crop, since then it has been corn. Fertilizer use on soybeans and oats has increased less rapidly and oats received less fertilizer in 1961 than 7 years earlier.

Correspondingly estimates of annual application rates of principal plant nutrients to individual crops were made for other states. Often crops other than those analyzed for Indiana were included in the analysis. In most cases the analysis covered the years 1927-1961. It started later when crops did not receive any fertilizer in earlier years or the rates of application were small enough to be omitted. Estimates for 1960 and 1961 were based on extrapolated 1954-59 trends of application rates. These rates were adjusted according to 1960/61 total state nutrient consumption by methods described earlier. Estimates of fertilizer application rates, covering the years 1939 to 1961, are tabulated in Appendix C by states and crops

Weather

Year to year changes in weather affect annual crop yields. They obscure the impact of technological yield variables. During later stages of this analysis estimates of annual changes in crop yields due to technological crop yield variables will be made. If the validity of these estimates is to be tested a weather variable is required. Two methods of constructing weather indices were considered, both were used before by other research workers. A new set of phenological state-crop weather indices was estimated.

Thompson employed multiple curvilinear regression analysis to separate weather effects from technology effects on corn and soybean yields (10). Using state data he regressed annual crop yields on time, precipitation and temperature data of Corn Belt states for the years 1930 to 1962. In his analysis state crop yields were regressed on 17 weather variables and one time trend variable and in two out of ten regression equations 19 weather variables were included. The F-values of the analysis of variance of these regression equations tested significant at one percent levels of significance. Standard errors and t-test values of individual regression coefficients were not reported. In an earlier "Evaluation of Weather Factors in the Production of Corn" by the same author "Combinations of weather variables were selected by excluding those with low correlation coefficients and regression coefficients with low t-values" (9, p. 6). In five regression equations of state corn yields 14 out of 26 regression coefficients of weather variables did not test significant at 10 percent levels of significance. Selecting weather variables by t-test values becomes burdensome if many crops and states are to be analyzed. Selection of 19 weather variables and one time trend variable is not permissable from a statistical point of view if the analysis is to cover time periods of twenty-one years or less. In the present study shorter time periods were analyzed as data requirements for state variety indices could not be met for earlier years.

Phenological weather indices have been constructed by several research workers. Most recently procedures of constructing such indices were described by Shaw and Durost (34). Their method of analysis is related to those of earlier studies by G.L. Johnson (35), D.E. Hathaway (36) and J.L. Stallings (37). In these studies test plot yields at experimental stations were used to construct weather indices. It was assumed that annual deviation from trend lines fitted to test plot yield represent annual weather effects on yields. By aggregation of percentage ratios of actual test plot yields over trend yields annual weather indices for crops and regions were estimated. In the latest study by Shaw and Durost 9-year moving averages were used as first approximations to trend line values. Yields 15 percent above or below trend line values were replaced by linearly interpolated values between mean yields of groups of average-weather years (34, p. 11). Trend yields were then smoothed out by 5-year moving averages. Weather indices for corn in Iowa were constructed by aggregation of indices over nine crop reporting districts. Annual corn production figures of individual crop districts were adjusted by local weather indices and then used as aggregation weights for estimating weather index of Iowa corn. This index was constructed for corn in Iowa only, other crops and states were not analyzed because demonstration of estimation procedures was the principal purpose of this investigation. In an earlier study Stallings computed phenological weather indices for a number of crops and locations. Beginning (in some cases) with the year 1900 he computed 14 station-location indices for wheat, 7 for oats, 6 for corn, 3 each for barley, cotton and tobacco and 1 station-location index for soybeans. Stallings' index series ended during the early fifties. The U.S. wheat weather index series was extended to 1956, but was based on only three station-locations after 1955 (37, pp. 55, 56). Also the U.S. index of corn was extended to 1956 but was based on three test locations after 1951 and only one test location after 1953 (37. p. 28). Other U.S. weather indices of crops were based on three station-locations or less, a U.S. soybean weather index was derived from test yields of one station-location (37, p. 63). Since the current study concentrated on analysis of crop yield changes of the last two decades Stallings' weather indices could not be used due to insufficient geographic and temporal coverage over the last decade. If phenological weather indices were to be used additional data were required.

In the present study state weather indices were derived from test plot yield data of uniform cooperative crop nursery tests and state corn yield tests. Procedures employed in this study for developing crop weather indices may be illustrated by showing how the North Dakota wheat weather index was derived. It was assumed that changes in test plot yields were caused by replacement of older by newer varieties and by year to year changes in weather. North Dakota wheat weather indices were calculated for 7 station-locations: Fargo, Langdon, Edgeley, Dickinson, Mandan, Williston and Minot. Wheat yield tests were not conducted at all 7 locations every year but at least 4 test locations were used for index computations of any one year. At each station-location test yields of three wheat varieties, i.e., Ceres, Thatcher and Mida, were included and for each variety weather indices were computed. Fargo variety test yields and annual weather indices of each variety are tabulated in columns 1 to 6 of Table 3.15. The station wheat weather index is listed in column 7. It was computed by averaging annual weather indices over varieties. The Fargo index was one of seven station indices in North Dakota. Not all station indices covered the same period of years. Three indices displayed discontinuities, the maximum being a 6-year interruption of tests at Mandan from 1941 to 1946. No wheat variety tests were conducted at station-location Minot prior to 1945. Tests at Edgeley, Dickinson and Langdon extended over the 32-year test period, tests at the latter two stations being conducted in each of 32 years as in the case of Fargo tests. The North Dakota wheat weather index was then derived by averaging individual state indices. A graphic illustration of the North Dakota wheat weather index is presented in Figure 3.8. Estimates of wheat yields of North Dakota are depicted in Figure 3.9 for the same years. Comparison between Figures 3.8 and 3.9 discloses close resemblance between the weather index and annual changes in crop yields. It should be emphasized that no trend lines were fitted for derivation of the North Dakota wheat weather index and that all station indices received identical weights when aggregated annually.

Essentially the same procedure was used for constructing state crop weather indices of other crops and states. In the case of soybeans acreage weights were used for aggregating station indices over maturity groups. State hay weather indices were derived from data on pasture

Table 3.15. Wheat weather index and related data, Fargo, North Dakota, 1929 to 1960[a]

Year	Test Yields of Spring Wheat Varieties: Ceres Bu.	Ceres Index	Thatcher Bu.	Thatcher Index	Mida Bu.	Mida Index	Fargo Spring Wheat Weather Index
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1929	51.2	1.42					1.24
1930	41.4	1.65					1.65
1931	35.0	1.39					1.39
1932	33.3	1.33					1.33
1933	29.9	1.19					1.19
1934	17.3	.69	14.2	.54			.62
1935	20.3	.81	31.6	1.20			1.00
1936	9.8	.39	10.0	.38			.38
1937	20.2	.80	30.1	1.14			.97
1938	23.2	.92	30.7	1.17			1.04
1939	26.1	1.04	26.3	1.00			1.02
1940	17.5	.70	19.4	.74	19.7	.71	.72
1941	23.6	.94	22.0	.84	28.0	1.01	.93
1942	42.6	1.70	38.3	1.46	48.0	1.73	1.63
1943	17.2	.69	21.1	.80	24.0	.87	.79
1944	18.2	.73	22.4	.85	23.1	.83	.80
1945	24.3	.97	26.7	1.02	27.7	1.00	1.00
1946	27.1	1.08	26.5	1.01	24.6	.89	.99
1947	22.5	.90	22.7	.86	23.2	.84	.87
1948	27.2	1.08	28.6	1.09	27.1	.98	1.05
1949	28.9	1.15	26.6	1.01	29.2	1.05	1.07
1950	25.8	1.03	32.5	1.24	32.2	1.16	1.14
1951	37.7	1.50	38.2	1.45	35.3	1.27	1.41
1952	18.7	.75	16.9	.64	17.7	.64	.68
1953	16.6	.66	21.5	.82	17.4	.63	.70
1954	12.6	.50	16.6	.63	14.5	.52	.55
1955	19.9	.79	19.1	.73	24.0	.87	.80
1956	32.8	1.31	36.9	1.40	33.8	1.22	1.31
1957	33.0	1.31	39.9	1.52	41.1	1.48	1.44
1958	29.9	1.19	31.4	1.19	28.3	1.02	1.13
1959	16.9	.67	22.1	.84	23.8	.86	.79
1960	21.2	.84	37.9	1.44	39.9	1.44	1.24
Average	25.1	1.00	26.3	1.00	27.7	1.00	

[a]Source: References; Wheat.

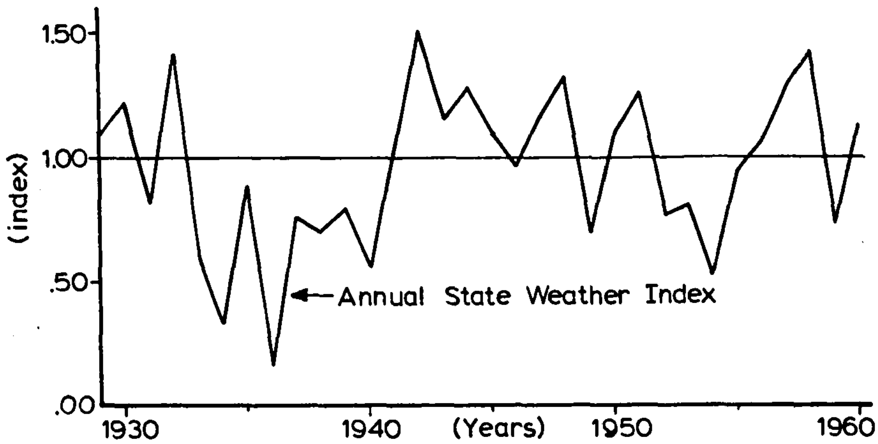


Figure 3.8. Estimated wheat weather index, North Dakota, 1929 to 1960

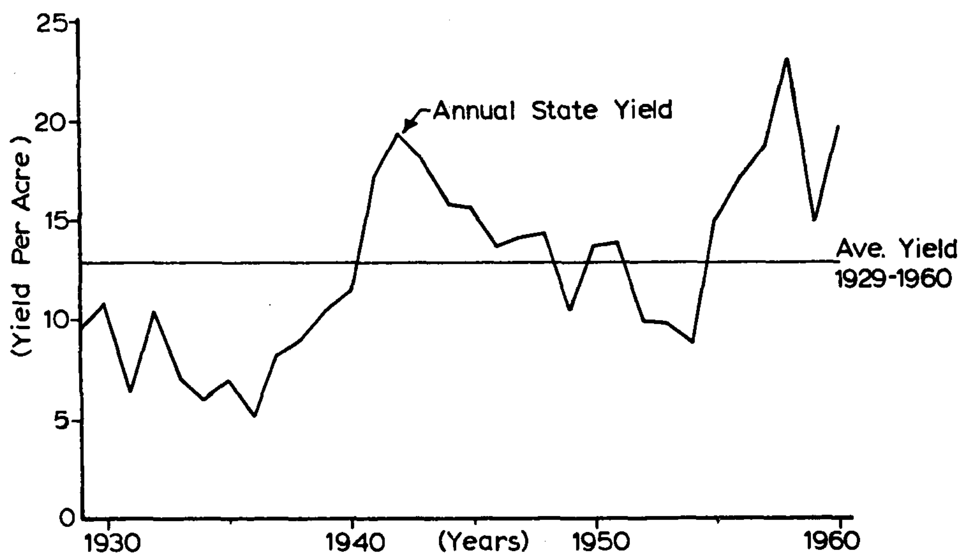


Figure 3.9. Wheat yield per harvested acre, North Dakota, 1929 to 1960

conditions. Annual data on pasture conditions have been published by the U.S.D.A. in Agricultural Statistics. The June 1st and September 1st pasture conditions were added annually and averaged over the years 1927 to 1960. Annual state hay weather indices were computed as ratios of annual over average conditions. Annual hay weather indices as well as all other crop weather indices are listed in Appendix D by crops and states.

Corn weather indices were estimated in a somewhat different manner. Annual average yields of all corn hybrid entries were calculated for corn test districts. The number of selected corn test districts varied from a minimum of two in Ohio to a maximum of eleven in Iowa. Annual average yields of all corn hybrid entries were aggregated for each state by weighting average yields of individual corn test districts by relative district acreages. These acreage weights were usually based on 10 to 20 year averages of individual crop districts but in some cases acreage weights were derived from shorter data series due to lack of data. Acreage weights used for aggregation of average corn test yields were identical to those used for aggregation of relative corn hybrid yields (Appendix Tables B.2 to B.20). Linear time trend lines were fitted to aggregated corn test yields. Their characteristics are presented in Appendix Table B.21. The b_1-regression coefficients estimate annual yield increases of corn test yields. Most of them tested statistically significant at one and/or five percent levels indicating that corn test yields increased over time. Average corn test yields and corresponding corn test yield trend values for Iowa are shown in Figure 3.10.[1] Annual

[1]Special corn yield tests for measuring effects of higher planting rates were excluded from average corn test yields of Iowa.

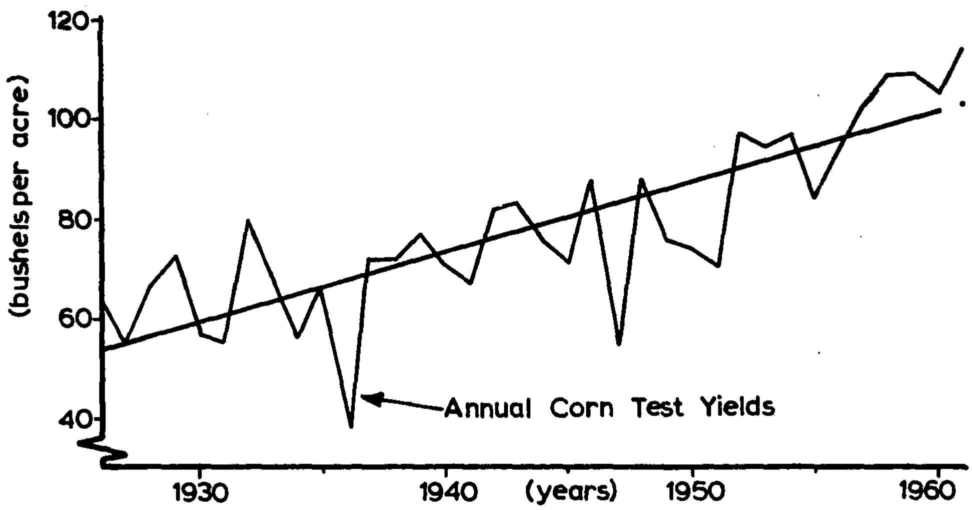


Figure 3.10. Corn test yields and trend yields, Iowa, 1926 to 1961

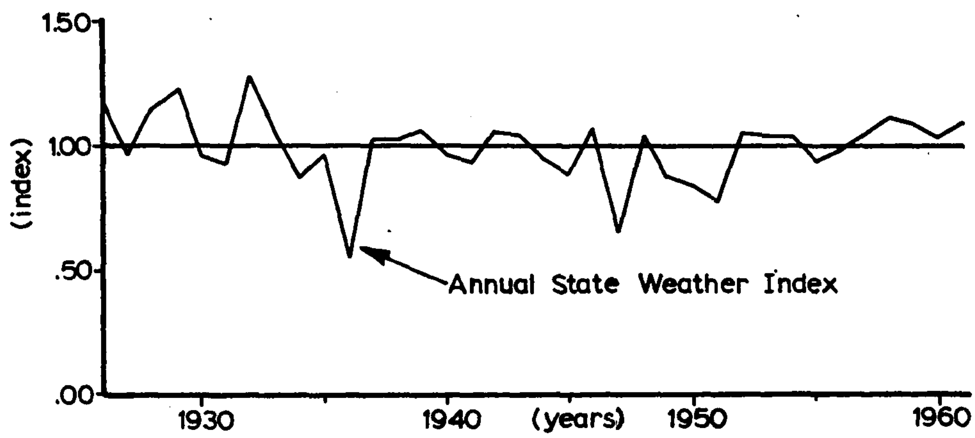


Figure 3.11. Estimated corn weather index, Iowa, 1926 to 1961

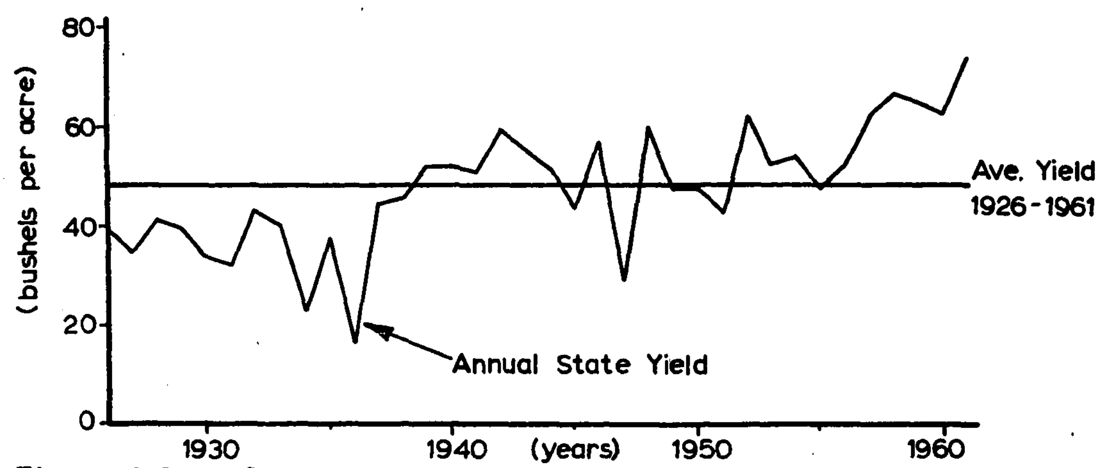


Figure 3.12. Corn yield per harvested acre, Iowa, 1926 to 1961

average corn test yields were divided by test yield trend values. Resulting yield ratios were taken as estimates of state corn weather indices. The Iowa corn weather index and Iowa state corn yields are shown in Figures 3.11 and 3.12 for comparison. This estimation procedure is based on the assumption that corn test yields advanced over time at a constant rate due to gradual increase in fertilizer application, introduction of new corn hybrids and other improved cultural practices. -Using experimental rather than state yield data assured that yield effects of annual changes in farm income, government programs, and changes in state corn acreage were not confounded with state weather indices. State corn weather indices are tabulated in Appendix Table D.2.

Other Crop Yield Variables

Aside from major forces like weather, fertilizer application and variety improvement other crop variables affect state crop yields. Insecticides and herbicides, trace elements, irrigation, drainage, liming, better tillage, timeliness of operation and other improved cultural practices exert a significant influence on crop yields. None of these will be considered individually but an attempt will be made to measure the net effect of these practices by including a net time trend variable in the production function analysis.

One additional variable, crop acreage, was considered explicitly. As acreage of any one crop is expanded yield per acre must eventually decline as the crop moves to areas less suited for production. Certain crops, e.g., corn and soybeans, are known to be more sensitive to geographic location than others. In order to estimate how strong such acreage effects were, a state crop acreage index was devised. It measured state crop acreages relative to trend acres. Annual trend areas were computed for all states and crops included in the present study. They were derived by fitting linear time trend lines to harvested acres by crops and states over the years 1939 to 1960. Since the Iowa corn analysis extended back to 1926 a second trend line was fitted to corn acreages of earlier years. The 1939 endpoint of the trend line of earlier years was made to coincide with the 1939 starting point of the linear trend line for later years by appropriate statistical methods. This procedure of fitting trend lines was chosen in order to make acreage trend lines comparable between crops and states over time. Moreover, by having all trend lines cover the same number of years they could be added to give a least square estimate of the acreage trend of sums of crop acreages by crops and states. Acreage trends prior to 1939 were all extended back to the year 1927 for the same reason. The year 1939 was chosen as a pivot point because most state crop analyses of this study began in 1939 or shortly thereafter. In Figures 3.13 and 3.14 annual Iowa corn acreages and Iowa corn acreage index values are plotted. These index values express annual corn acreages relative to trend line acreages for corn in Iowa. Similarly other state crop acreage indices were computed. In the case of grain sorghums the pivot point was set at 1949 as a marked rise in grain sorghum acreage occurred after 1949.

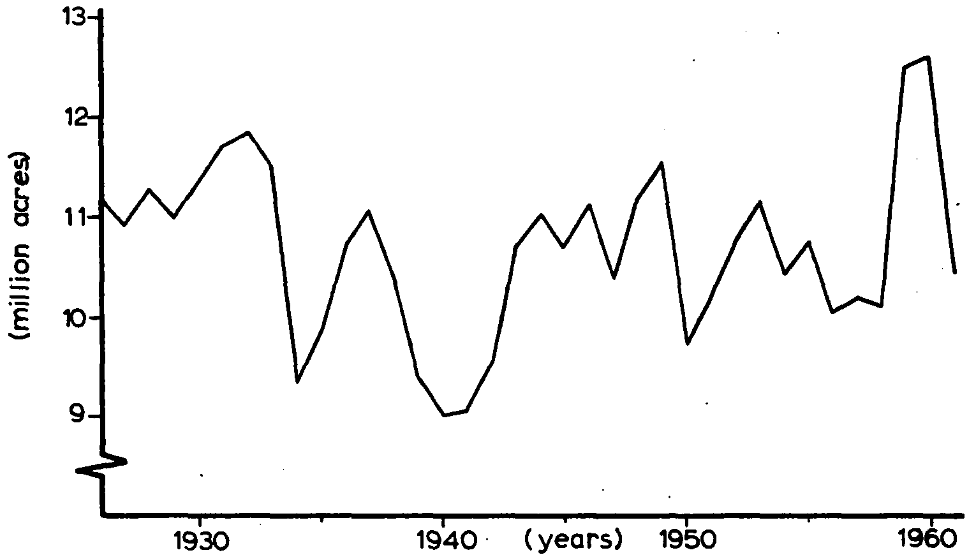


Figure 3.13. Harvested corn acreage, Iowa, 1926 to 1961

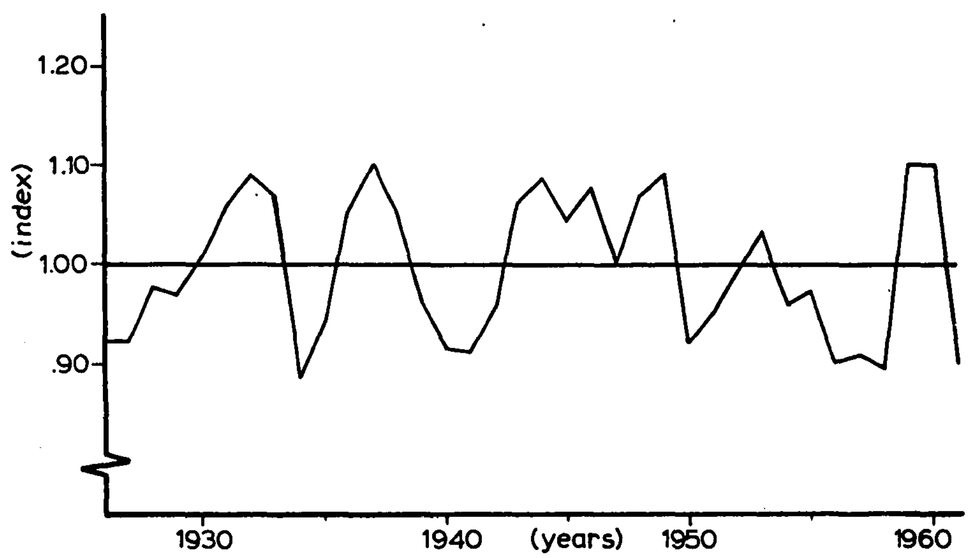


Figure 3.14. Estimated corn acreage index, Iowa, 1926 to 1961

CHAPTER IV

ESTIMATION OF STATE CROP PRODUCTION FUNCTIONS

In this chapter time series data of individual crops are summarized by states and regions. The end-result of this summary is a set of state crop production functions which provides the basis for economic analysis of crop yield technology. For validity of this analysis it is most important that effects of variables of crop yield technology are estimated with sufficient accuracy. Because crop variety improvements, rates of fertilizer application and other crop yield variables are highly correlated over time statistical estimation of their individual impact on crop yields becomes problematic. Statistical estimation procedures are examined first, crop variety improvements, rates of fertilizer application and response are presented next and estimates of state crop production functions are discussed last.[1]

Statistical Estimation Procedure

State crop production functions were derived by method of least square regression analysis. Estimated regression equations were linear in the logarithms and of the general form 4.1 where Y and $X_1,\ldots,X_n$

$$Y = b_o + b_1X_1 + \ldots + b_jX_j + \ldots + b_nX_n + e \qquad (4.1)$$

represent logarithms of the dependent and independent variables

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[1]For a comprehensive treatise on the production function technique and its application to agriculture see: Heady, E.O. Agricultural Production Functions, (38).

respectively, $b_o, \ldots, b_n$ are estimated regression coefficients and value e is the estimated residual error term. The usual assumptions were made: (1) Independent X-variates are measured without error and (2) residual errors are independently distributed with zero means and the same variance. If these assumptions hold true the method of least squares provides unbiased and minimum variance estimates of population parameters (39, p. 156). For empirical analyses these assumptions hold true to varying degrees. Independent X-variates are rarely if ever measured without error but often they are measured with sufficient accuracy. Also the assumptions about residual errors can often be satisfied within a permissable range of accuracy provided errors of specification are neglegible. To what extent violations of these assumptions may affect regression estimates has been summarized by Tweeten (40, pp. 46-74) and is, except for multicollinearity, not further discussed here.

Frequently, multicollinearity poses a problem in regression analyses of time series data. The problem of multicollinearity becomes severe if X-variates are highly correlated. For the extreme (but unlikely) case where two or more variates are perfectly correlated, the matrix of the sums of squares of the normal equations becomes singular and regression coefficients can not be estimated. If X-variates are not perfectly but highly correlated estimated regression coefficients tend to be unstable and their standard errors may become large (40, p. 60). In such cases the influence of individual X-variables on the dependent Y-variable often can not be estimated with a sufficient degree of reliability by the usual least squares regression method.

In the present study X-variates used for quantification of technological change were highly correlated. In Table 4.1 the frequency distribution of absolute values of simple correlation coefficients of five X-variates of corn yield data sets of 13 states are shown. Evidently correlation coefficients between corn hybrid indices, rates of fertilizer nutrient application and the time trend variable are very high, all 39 correlation coefficients test significantly different from zero at the one percent level of significance. This is in contrast to the other 91 correlation coefficients none of which tests significantly different from zero at the 1 percent level of significance. In view of the high correlation between some of the X-variates instability in the regression coefficients could be expected.

For preliminary testing of estimation procedures multiple regression equations were fitted to Iowa corn yield data by the usual method of least squares regression analysis. The equations were of the form

$$Y = b_o + vV + fF + aA + wW + tT + e \tag{4.2}$$

where Y, V, F, A, W and T are logarithms of Iowa corn yield, corn hybrid index, rate of fertilizer (nutrient) application per acre, acreage index, weather index and time in years, respectively. These variables were considered major determinants of state crop yields. The term e denotes the estimate of the error term. Estimated regression coefficients of three Iowa corn equations are listed in Table 4.2. All three equations contain the same set of variables. Equation I was estimated from 36 annual data sets covering the years 1926 to 1961, equation II was based on 18 data sets of the even numbered years 1926 to 1960 and equation III was derived from 18 data sets of the odd numbered years 1927 to 1961.

Table 4.1. Frequency distribution of absolute values of simple correlation coefficients between logarithmic X-variates of corn yield data sets of 13 states

X Variates	Absolute Values of Correlation Coefficients									
	.00-.09	.10-.19	.20-.29	.30-.39	.40-.49	.50-.59	.60-.69	.70-.79	.80-.89	.90-.99
Acre Index, Weather Index	5	5	1	2						
Acre Index, Hybrid Index	7	3	1	1	1					
Acre Index, Fert. Applic.	2	5	4	1		1*				
Acre Index, Time in Years	5	5	1	1	1*					
Weather Index, Hybrid Index	8	3	2							
Weather Index, Fert. Applic.	8	4	1							
Weather Index, Time in Years	9	4								
Hybrid Index, Fert. Applic.									9**	4**
Hybrid Index, Time in Years										13**
Fert. Applic., Time in Years									1**	12**
Frequency	44	29	10	5	2	1	0	0	10	29

**Tested statistically different from zero at the one percent level of significance (41, p. 174).

*Tested statistically different from zero at the five percent level of significance (41, p. 174).

Table 4.2. Regression coefficients of regression equations fitted to Iowa state corn yield data, 1926 to 1961

Coefficient of	Regression Coefficients of Equations I	II	III
Hybrid Corn Index	2.27**	3.57**	1.05+
Rate of Fertilizer Application per Acre	-.09**	-.09*	-.09**
Time Trend Variable	.07	.61+	.63*
Weather Index	1.25**	1.10**	1.19**
Acreage Index	.06	.39	-.35
Mult. Correlation	.94	.97	.95

**Tested statistically different from zero at the one percent level of significance (41, p. 46).

*Tested statistically different from zero at the five percent level of significance (41, p. 46).

+Tested statistically different from zero at the ten percent level of significance (41, p. 46).

Multiple correlation coefficients of these three equations ranged from .94 to .97 and in most cases regression coefficients tested statistically significant at one or five percent levels of significance. Coefficients of the acreage index[1] did not test significant at one or five percent levels and estimates ranged from -.35 to +.39. The weather index tested highly significant in all three equations and estimates were quite stable. Two coefficients of the time trend variable tested significant at ten and five percent levels and ranged from .07 to .63. All regression coefficients of fertilizer application were negative and tested significant at the one or five percent levels. They were very stable but highly unrealistic.

Numerous experiments conducted by Iowa State University show that corn yield response to fertilizer application is not negative but positive. Moreover, Iowa farmers have applied fertilizer to corn for years, they increased application rates considerably during the last decade from an estimated 7.4 pounds in 1950 to 57.5 pounds in 1961[2]. During the last three years Iowa farmers spent over 20 million dollars on corn fertilization annually. It would have been irrational to apply any fertilizer at all if the marginal productivity of fertilizer had been negative as all three equations in Table 4.2 imply. Also estimated regression coefficients of the hybrid corn index are very questionable in equations I and II even though they test significant at the one percent level of significance. In Chapter III it was shown that yields of corn hybrids commonly grown by farmers in Iowa (in 1952) were just as high as those

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[1]The acreage index refers to the ratio of annual acreage over trend acreage (see Chapter III, p. 78, herein).

[2]See Appendix Table C.4.

of corn hybrids grown in Iowa corn yield tests. Since the Iowa corn hybrid index was derived from yield performance of corn hybrids in these tests a one percent change in the Iowa corn hybrid index should correspond to a one percent change in the State corn yield. According to coefficients of equations I and II a one percent change in the hybrid corn index resulted in 2.27 and 3.57 percent yield changes. In equation III the corresponding yield change was estimated at 1.05 percent which could be considered more realistic even though the statistical significance of this estimate appeared to be lower. It might be suggested that these regression estimates were based on data of a single state and that estimates for other states might have compensated for unrealistic estimates of one state. However, Iowa produces traditionally more corn than any other state and therefore these contradictions of empirical evidence could not be ignored. The usual method of estimating regression equations was rejected as being unproductive of reliable estimates of the impact of crop yield technology in this study.

In order to obtain more realistic estimates the obstacle of multicollinearity, a possible cause of nonsensical estimates, was removed. To do so certain regression coefficients were estimated on the basis of empirical evidence and then incorporated in the production function analysis. The model of the new estimating equation 4.3 is similar to 4.2. Letters Y, V, F, A, W and T in 4.3 denote logarithms of annual Iowa

$$Y = b_o' + v'V + f'F + a'A + w'W + t'T + e' \tag{4.3}$$

$$Y' = Y - v'V - f'F \tag{4.4}$$

$$Y' = b_o' + a'A + w'W + t'T + e' \tag{4.5}$$

corn yield, corn hybrid index, rate of fertilizer application, acreage index, weather index and time trend variable as before. In equation 4.2 the letter f represented the annual rate of fertilizer (nutrient) application per acre but in equation 4.3 f' denotes annual fertilizer (nutrient) response which will be defined shortly. Estimating procedures for 4.3 are not the same as for 4.2 and regression coefficients b_0', v', f', a', w', t' in 4.3 are expected to differ from b_0, v, f, a, w, t in 4.2. To obtain more reliable regression estimators coefficients V' and f' were determined first, new annual Y' values were derived according to identity 4.4 and then coefficients b_0', a', w' and t' were estimated by the usual least squares regression method as indicated by 4.5. It should be noted that independent variates A, W and T of equation 4.5 were not highly correlated. Most of their correlation coefficients ranged from .00 to .19 in absolute value and only one out of a sample of 39 (Table 4.1) tested significant at the one percent level. Multicollinearity between state corn hybrid index, rate of fertilizer application and time could not affect final regression estimate 4.3 because coefficients of these highly correlated variables were determined independently. From a statistical point of view such a procedure is quite permissible and one additional assumption is sufficient: Predetermined regression coefficients are measured without error. For example, if predetermined coefficients b_1' and b_2' are wrong identity 4.4 does not hold and estimated coefficients of 4.5 will be biased. Since realiable predetermined b_i- coefficients are a prerequisite for applicability of this method it becomes important that they are measured with a sufficient degree of accuracy. The earlier assumption of error-free independent variates still applies but is more stringent for variates with predetermined coefficients, e.g., V and F in 4.3. An attempt was made here to predetermine yield response due to crop variety improvement and fertilizer application.

Crop Variety Improvement

State crop variety indices were derived for all major crops. They were based on yield performance as well as rate of adoption of newly developed varieties and indexed over base year period 1947 to 1949. If, for example, a state crop variety index changed from 1.00 in 1948 to 1.08 in 1956 it implied that ceteris paribus state crop yield increased by eight percent due to adoption of higher yielding crop varieties by farmers. State crop variety indices were incorporated in state crop production functions with a fixed coefficient of magnitude 1.0 as in 4.6. The

$$Y = b_o + 1.0V + f'F + a'A + w'W + t'T + e' \qquad (4.6)$$

magnitude of the predetermined regression coefficient follows from the definition of the crop variety index.[1] According to previous terminology (Chapter II, p. 23) crop variety improvement is incorporated in the production function as a neutral technological change which infers that crop variety improvement raises marginal productivities of all other factors equiproportionately. Changes in the variety index cause a shift in the production function. Since the exponent of the crop variety improvement index has been fixed at 1.0 the magnitude of the shift is proportionate to the relative change of the index. Validity of the production

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[1]All variables (denoted by capital letters in 4.6) are logarithms as defined in 4.3 above.

function estimates depends strongly on the accuracy of the crop variety indices.

State crop variety indices were estimated according to procedures outlined in the previous chapter. Complete data sets of crop variety indices, estimates of variety adoption and relative yield performance of individual varieties are listed in Appendix Tables A.1 to A.70. State variety indices and regional adoption of major crop varieties during the 1939-60 period are shown graphically in Figures 4.1 to 4.46. The order of presentation is arbitrary and of no particular significance here.

Wheat Annual state wheat variety indices of Lake States Minnesota, Wisconsin, and Michigan are illustrated in Figure 4.1. Major varieties responsible for index changes are shown in Figure 4.5 in terms of percentage of harvested acreage of the Lake State region. For purposes of clarity and convenience only those wheat varieties which occupied at least ten percent of the regional acreage in any one year are shown even though a greater number of varieties was included in index computations. In Figure 4.5, for example, the regional acreage distribution of only eight wheat varieties is shown whereas relative test yields of 33 different varieties were used for construction of the three wheat variety indices. Five Hard Red Spring Wheat varieties, i.e., Thatcher, Rival, Mida, Lee and Selkirk were largely responsible for raising the Minnesota wheat variety index from below .90 in 1939 to over 1.20 in 1959. In Minnesota Thatcher was grown for yield comparisons in 154 tests over a thirty-two year period. Compared to Thatcher, variety Rival yielded 1.11 times as much in 75 yield comparisons, Mida yielded 1.13 times as much in

77 tests, Lee yielded 1.21 times as much in 67 tests and Selkirk yielded 1.41 times as much in 39 tests. Variety Selkirk, first developed and released in Canada, was rapidly adopted in Minnesota and throughout the spring wheat region. In Minnesota, for example, variety Selkirk occupied less than one percent of the acreage in 1954 but more than 90 percent of the acreage in 1959 (42, p. 29). It was rapid adoption of these superior varieties which caused the steep rise of the Minnesota Wheat Variety Index in recent years. In Michigan the White Winter Wheat variety Genessee which caused the strong upward trend of the late fifties occupied about two percent of the Michigan wheat acreage in 1954 but over 60 percent in 1959. The Wisconsin wheat variety index moved at a much slower rate because spring wheat varieties which replaced variety Henry were not much superior in yield. Variety Henry caused the Wisconsin wheat variety index to rise sharply from 1944 to 1949 when farmers expanded the acreage of this variety from less than one to over 70 percent. Since the Wisconsin wheat acreage is quite small compared to Minnesota and Michigan acreages, variety Henry accounted for only three percent of the Lake States wheat acreage and is therefore not shown in Figure 4.5.

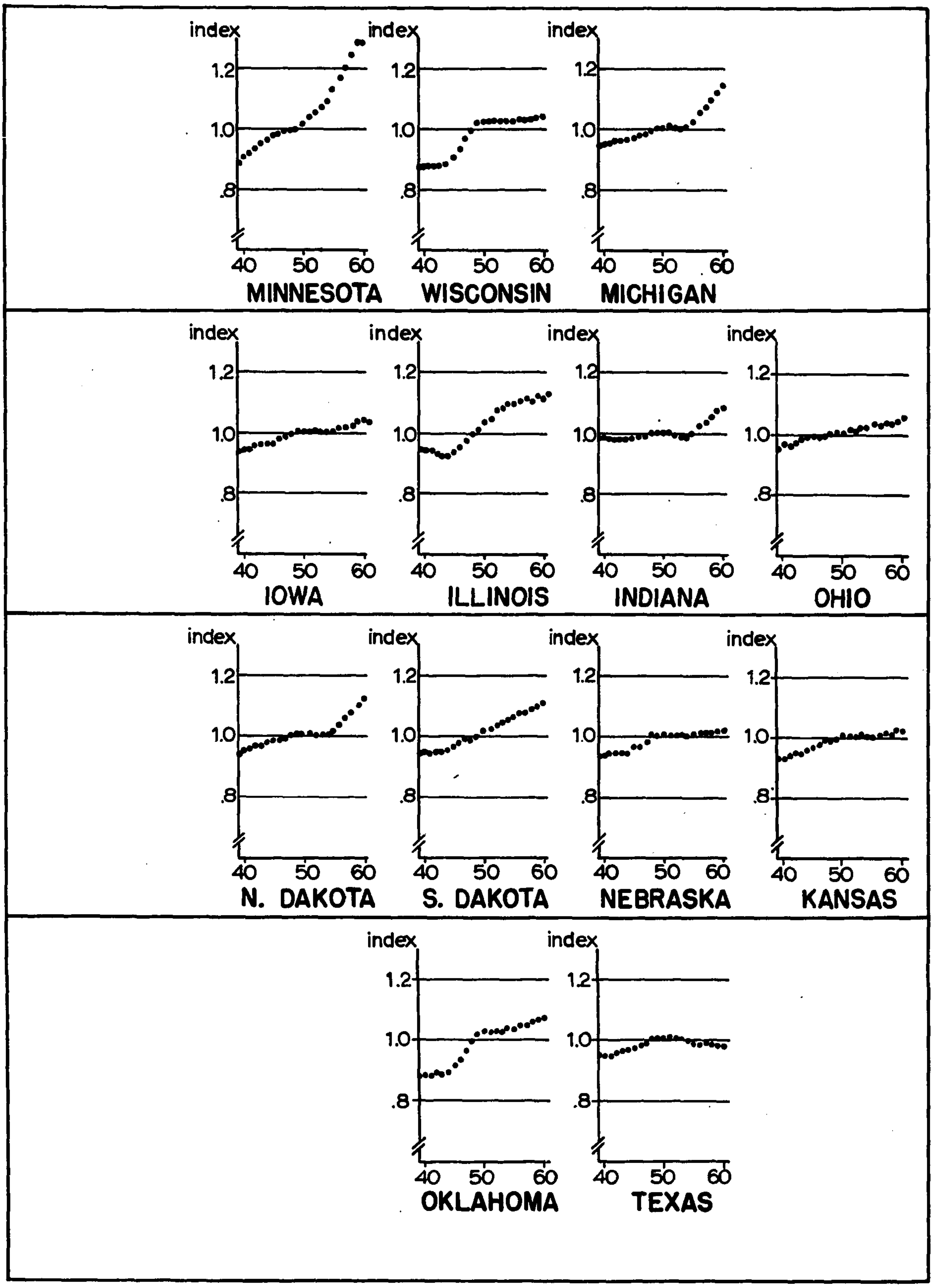
Similarly variations between wheat variety indices of other regions and states can be attributed to differences in yield performance and adoption rates of individual wheat varieties. A short discussion must suffice. Among Corn Belt states the Illinois wheat variety index advanced most, followed by Indiana, Iowa and Ohio as illustrated in Figure 4.2. In computing wheat variety indices of Corn Belt states over 40 varieties were included, relative acreages of the more important ones

Figure 4.1. Annual wheat variety indices, Lake States, 1939 to 1960

Figure 4.2. Annual wheat variety indices Corn Belt States (excl. Missouri) 1939 to 1960

Figure 4.3. Annual wheat variety indices, Northern Plains States, 1939 to 1960

Figure 4.4. Annual wheat variety indices, Southern Plains States, 1939 to 1960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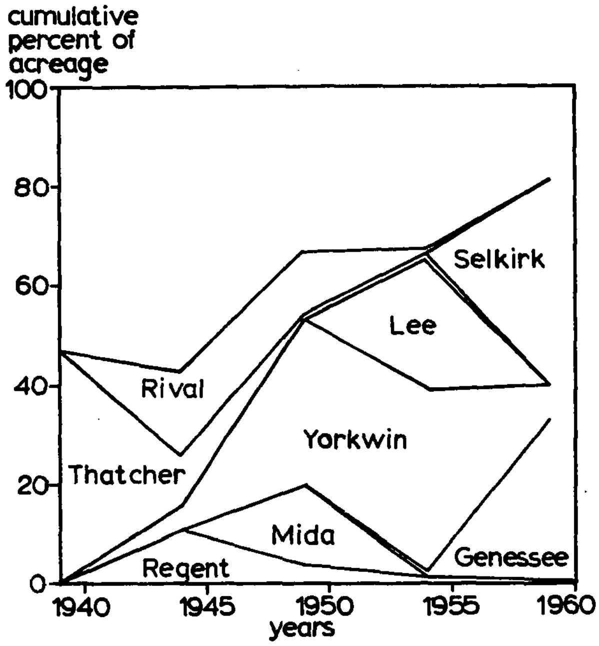


Figure 4.5. Wheat variety distribution, Lake States, 1939 to 1959

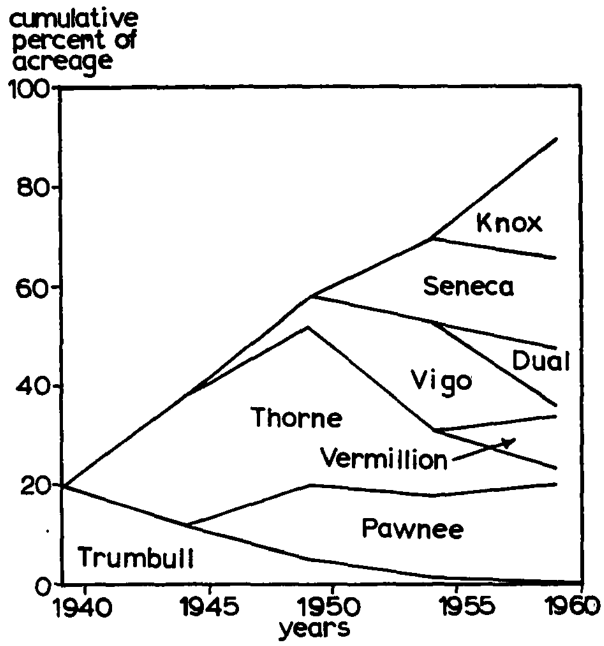


Figure 4.6. Wheat variety distribution, Corn Belt, 1939 to 1959

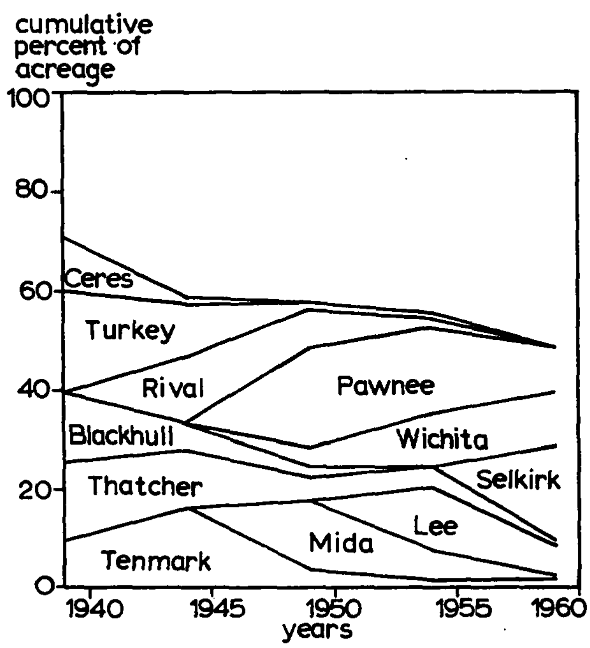


Figure 4.7. Wheat variety distribution, Northern Plains, 1939 to 1959

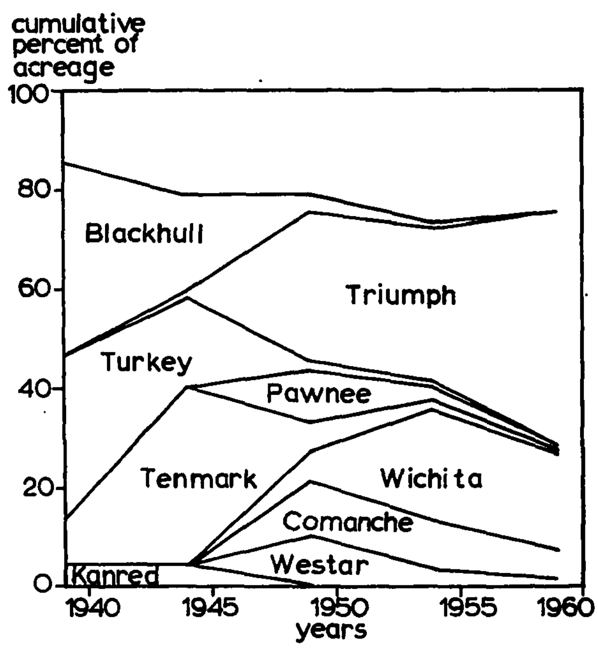


Figure 4.8. Wheat variety distribution, Southern Plains, 1939 to 1959

are depicted in Figure 4.6. In recent years varieties Pawnee, Vermillion, Dual, Seneca and Knox have become predominant. In earlier years only two varieties, i.e., Trumbull and Thorne, occupied large acreages and many other varieties, specified in tables of Appendix A, accounted for the remainder of the acreage. - In the Northern Plains two major classes of wheat were grown. Hard Red Winter Wheats, grown primarily in Kansas and Nebraska, occupied the larger acreage. Hard Spring Wheats, grown extensively in the Dakotas, were lower yielding but of superior quality (43). Variety improvement in the Hard Red Spring Wheat region appears to have been stronger than in the Hard Red Winter Wheat region. Again adoption of spring wheat varieties Mida, Lee and Selkirk was responsible for the growth of the wheat variety indices of North and South Dakota. Wheat variety indices of Nebraska and Kansas leveled off during the late forties to rise during the earlier years as shown in Figures 4.3 and 4.7. Pawnee was still widely grown during the late fifties but Wichita has taken over some of the Pawnee acreage. Relative test yields of Pawnee and Wichita were nearly identical in Kansas. Newly introduced varieties in Nebraska as in Kansas were not superior in yield comparisons to Pawnee which explains why wheat variety indices of Kansas and Nebraska remained practically at the same level. Wheat variety indices of Southern Plains states changed more rapidly during the forties than during later years because variety Triumph was adopted during the earlier period but not replaced by superior yielding varieties in more recent years. In summary wheat variety improvement, as measured by state wheat variety indices in terms of relative yielding ability, was more pronounced during the forties than during the fifties in the Hard Red Winter Wheat region but continued strongly in the Hard Red Spring Wheat region, the White Wheat region of Michigan and the Corn Belt states. Quantitative estimates of yield increase due to variety improvement will not be presented here but in the next chapter.

Oats Variety indices of oats are shown in Figures 4.9 to 4.12 and annual percentage distributions of four major producing regions are depicted in Figures 4.13 to 4.16. Evidently oats variety indices of the Lake States advanced strongly during the last decade. As Figure 4.13 illustrates the initial rise was caused by adoption of Bonda and Clinton after 1945 and was continued by a number of new varieties, among them Ajax, Branch, Garry and Rodney. Oats variety indices of Corn Belt states rose abruptly after 1945 which again coincides with the quick expansion of Clinton acreage as shown in Figures 4.10 and 4.14. Clinton and its reselections dominated the oats acreage of the Corn Belt until Nemaha, Cherokee, Mo. 205, Clintland and Newton gradually replaced them during the last decade. In 1949 Clinton occupied two-thirds of the oats acreage of the Corn Belt, thereafter newly adopted varieties maintained but failed to raise oats variety indices across Corn Belt states. Oats variety indices of Northern Plains states moved gradually upward as newer varieties replaced others but no single variety exceeded one quarter of the regional acreage in any one year. Oats variety indices of the Southern Plains states differed markedly between Texas and Oklahoma. While the Texas index changed very little, the Oklahoma index climbed rapidly. The remarkable growth of the Oklahoma oats index is to be attributed to the shift from spring to winter oats varieties. In 1940 about two-thirds of the Oklahoma oats acreage was planted to spring oats varieties, by 1961 about 95 percent of the oats acreage was occupied by higher yielding winter oats varieties. No comparable shift with corresponding yield effects took place in Texas. In contrast to wheat more than 35 oats varieties were grown in each production region and a greater number of varieties exceeded ten percent of the regional acreage. In spite of the more rapid turnover oats variety indices did not appear to advance at a correspondingly faster rate.

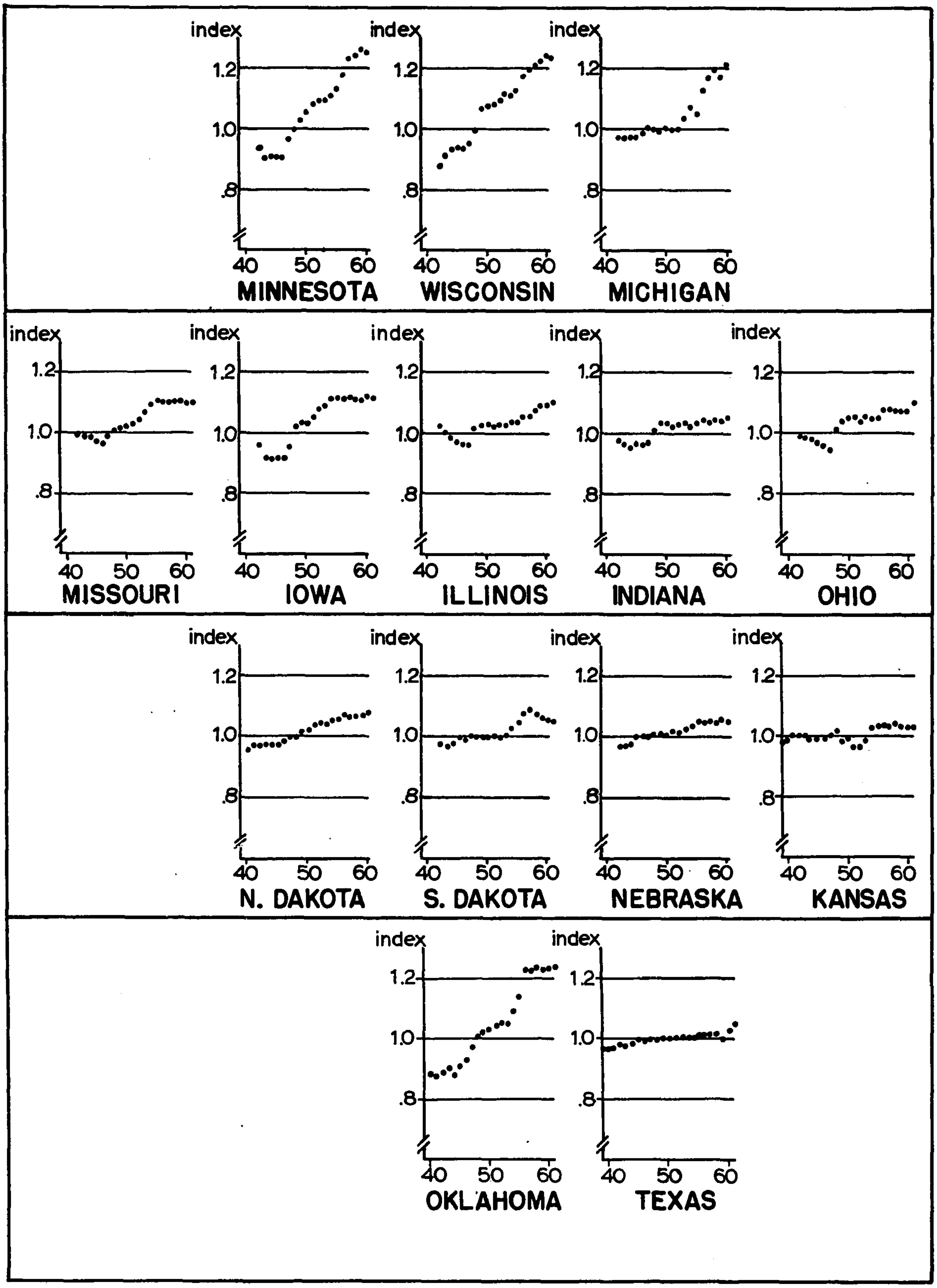
Soybeans Variety indices were computed for eleven states, most of them advanced strongly as shown in Figures 4.17 to 4.19. Major soybean varieties, introduced in more recent years, have been developed for north-south maturity groups which are essentially confined to different producing regions. In the Lake States, varieties best suited for early northern maturity requirements were not available during the forties but introduced and adopted during the fifties. Consequently soybean variety indices of the Lake States show a stronger increase during the last decade. Soybean variety indices of the Corn Belt advanced quite uniformly with the apparent exception of the Iowa index. The Iowa soybean variety index leveled off shortly after 1950 because variety Hawkeye replaced Lincoln sooner than in other Corn Belt states and Clark, a higher yielding but late maturing variety, was not widely adopted in Iowa. Instead Iowa farmers grew variety Chippewa, a newly developed but earlier maturing variety. Iowa farmers prefer early maturing varieties because harvesting operations of late varieties might interfere with corn harvesting operations.

Figure 4.9. Annual oats variety indices, Lake States, 1942 to 1960

Figure 4.10. Annual oats variety indices, Corn Belt States, 1942 to 1960

Figure 4.11. Annual oats variety indices, Northern Plains States, 1942 to 1960

Figure 4.12. Annual oats variety indices, Southern Plains States, 1942 to 1960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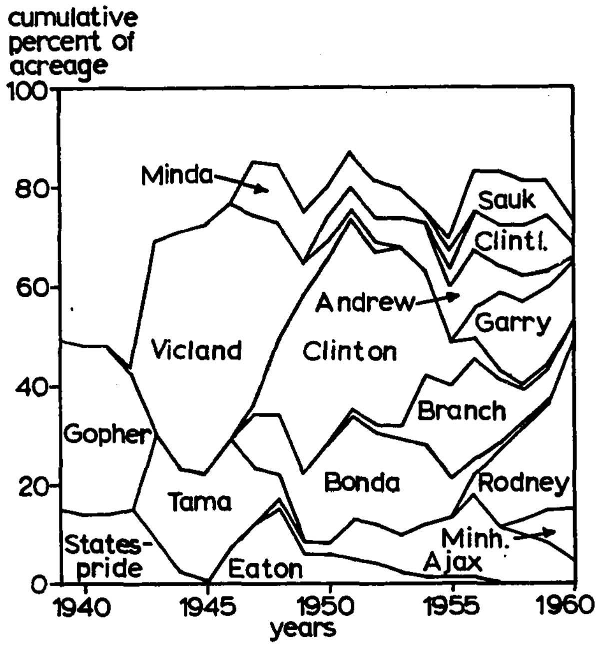


Figure 4.13. Oats variety distribution, Lake States, 1939 to 1960

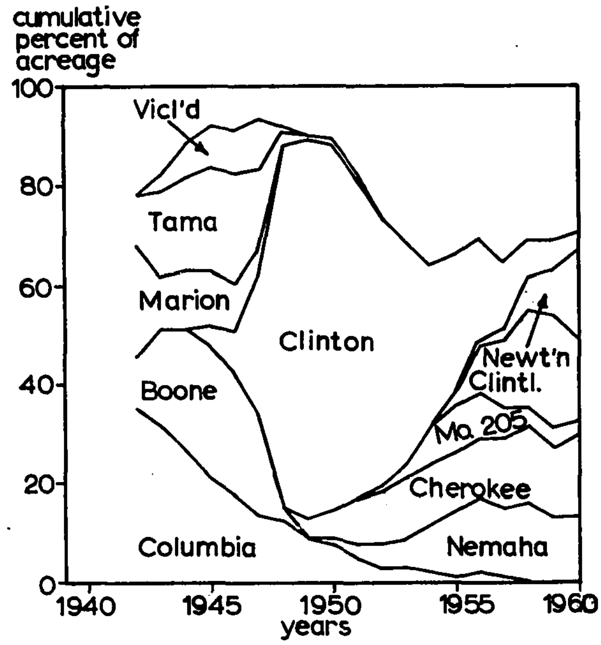


Figure 4.14. Oats variety distribution, Corn Belt, 1942 to 1960

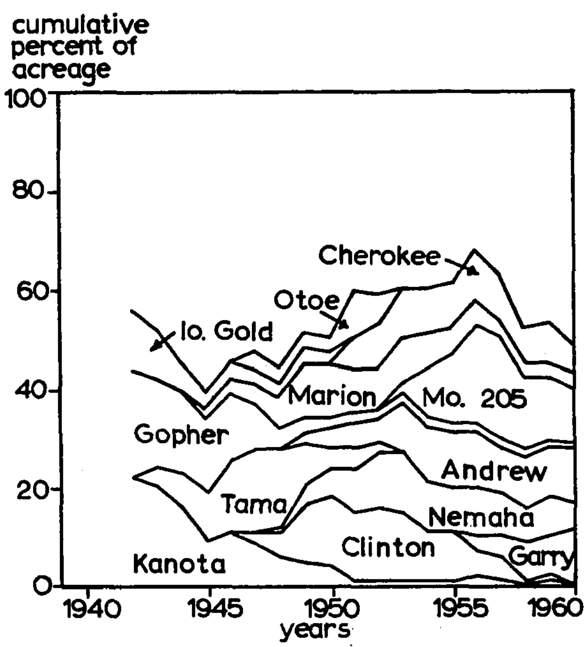


Figure 4.15. Oats variety distribution, Northern Plains, 1942 to 1960

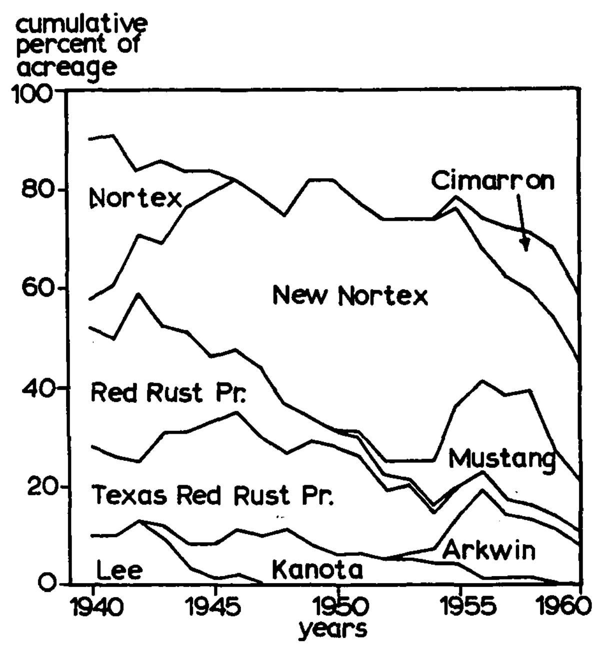
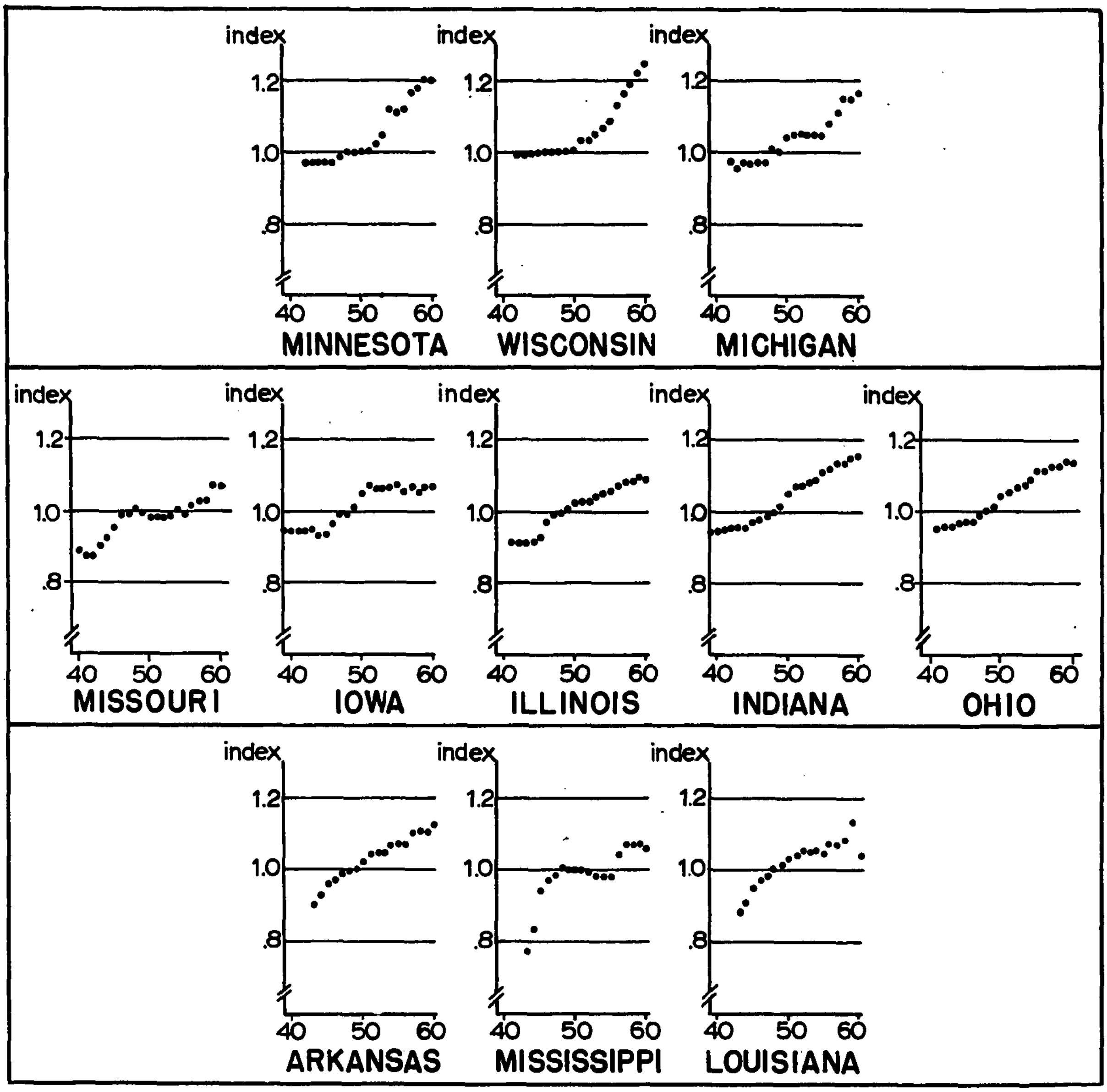


Figure 4.16. Oats variety distribution, Southern Plains, 1940 to 1960

Figure 4.17. Annual soybean variety indices Lake States, 1942 to 1960

Figure 4.18. Annual soybean variety indices Corn Belt States, 1941 to 1960

Figure 4.19. Annual soybean variety indices Delta States, 1943 to 1960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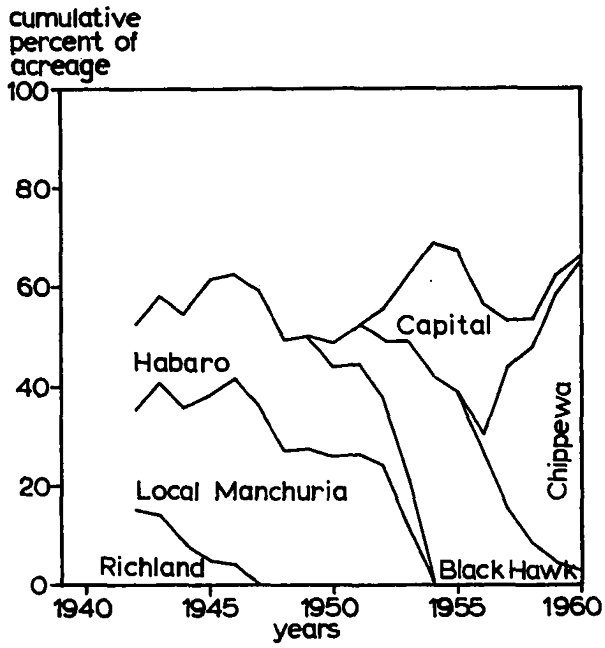


Figure 4.20. Soybean variety distribution, Lake States, 1942 to 1960

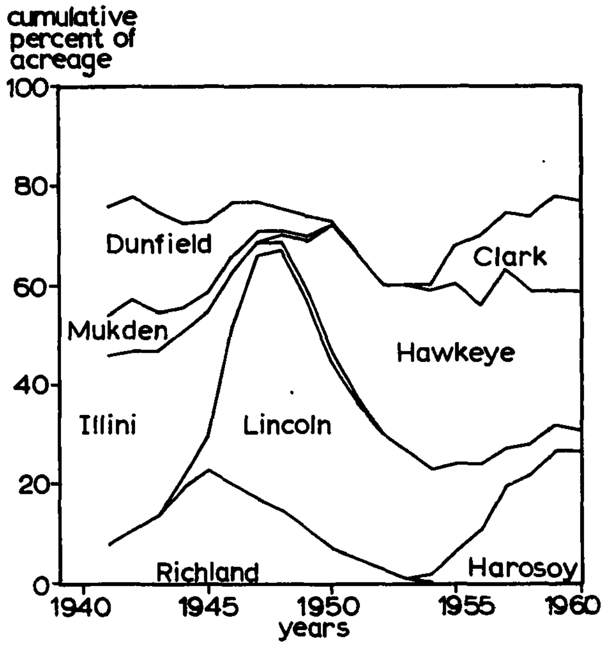


Figure 4.21. Soybean variety distribution, Corn Belt, 1941 to 1960

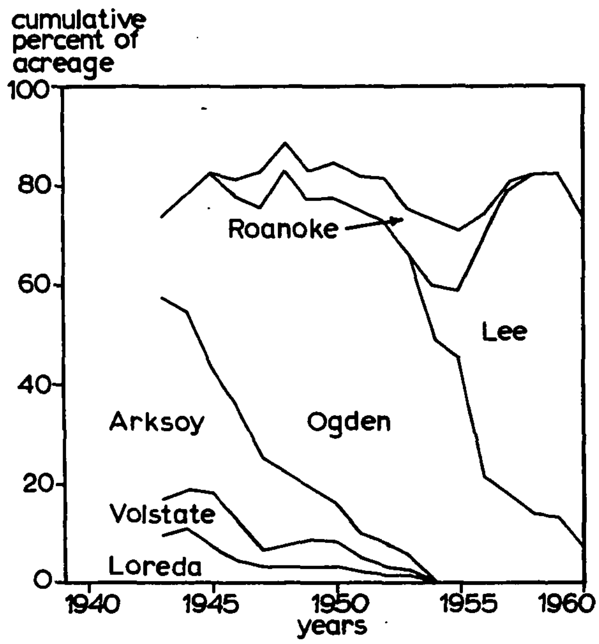


Figure 4.22. Soybean variety distribution, Delta States, 1943 to 1960

As a rule earlier soybean varieties yield less than late maturing varieties and consequently the Iowa soybean variety index has remained practically unchanged during the fifties. Soybean variety indices of Delta States Arkansas and Louisiana progressed at very similar rates but the Mississippi index advanced irregularly. In Mississippi Arksoy, a comparatively low yielding variety, was grown extensively during earlier years, its subsequent replacement caused a steep climb of the index but then Roanoke was adopted which prevented further increase until variety Lee spread rapidly over the Mississippi soybean acreage. Over the past two decades the soybean acreage of the United States has more than doubled. It is quite likely that introduction of new and locally better adapted soybean varieties was at least partly responsible for this acreage expansion. At the same time soybean variety improvement increased average yields significantly.

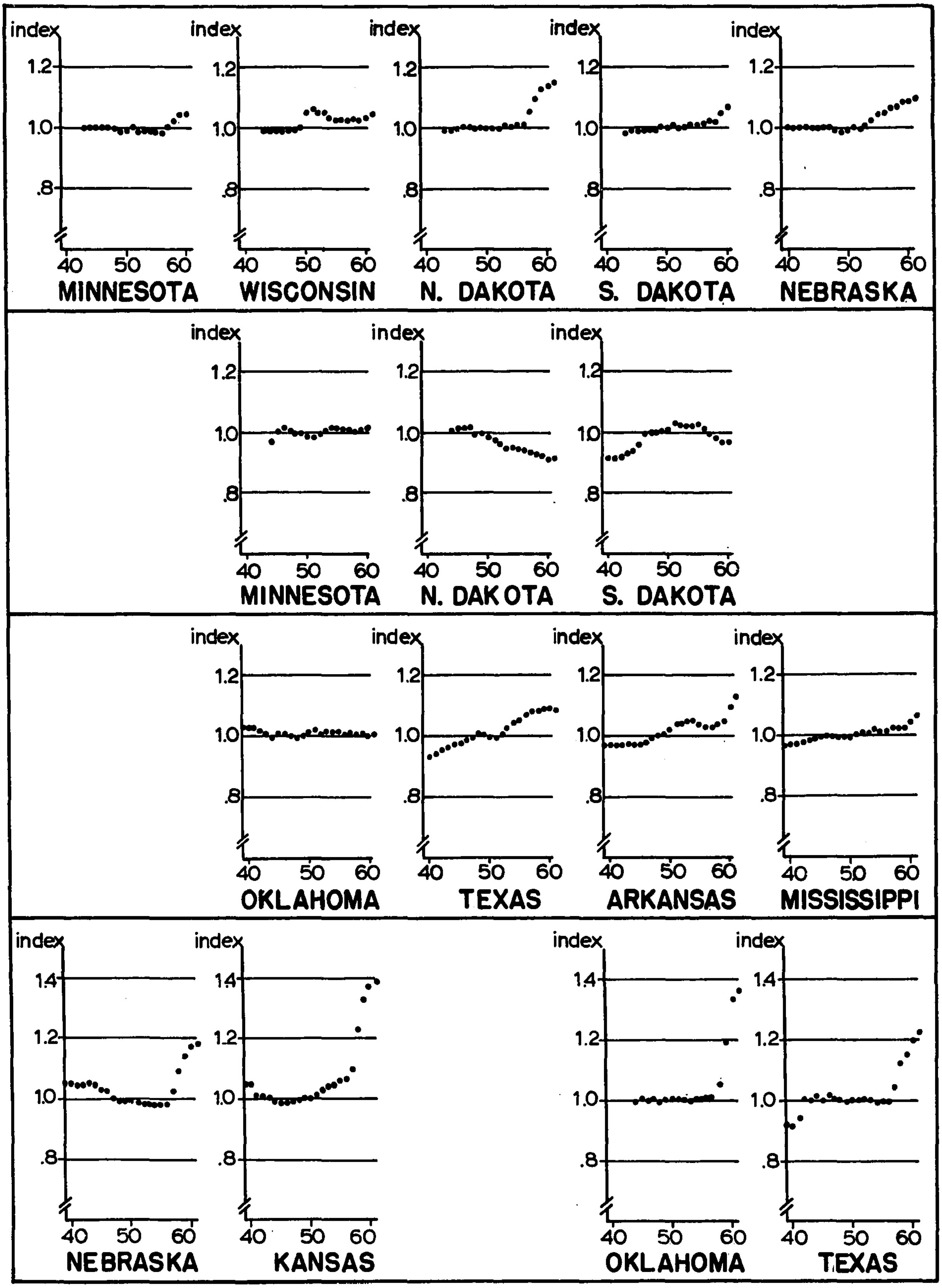
Barley, flax, cotton and grain sorghum Variety indices and acreage distributions of barley, flax, cotton and grain sorghum are presented in Figures 4.23 to 4.26 and 4.27 to 4.34 respectively. Barley variety indices were computed for two Lake States and three Northern Plains States. Barley variety indices of different states were alike, all remained fairly constant during the forties but rose during the late fifties. As illustrated in Figures 4.27 and 4.28 variety Kindred replaced Wisconsin 38 and predominated over other varieties until Traill, a higher yielding variety and of good malting quality, was released in 1956 and widely accepted. - While turnover of barley varieties was slow, flax varieties grown in the same regions, i.e., Minnesota, North and South Dakota, were replaced more frequently, at least on part of the acreage.

Figure 4.23. Annual barley variety indices, five States of the Lake States and Corn Belt regions, 1943 to 1960

Figure 4.24. Annual flax variety indices, three States of the Lake States and Northern Plains regions, 1944 to 1960

Figure 4.25. Annual cotton variety indices, four States of the Southern Plains and Delta States regions, 1940 to 1960

Figure 4.26. Annual grain sorghum variety indices, four States of the Northern and Southern Plains regions, 1944 to 1960



index
1.2
1.0
.8
40 50 60
MINNESOTA
WISCONSIN
N. DAKOTA
S. DAKOTA
NEBRASKA
MINNESOTA
N. DAKOTA
S. DAKOTA
OKLAHOMA
TEXAS
ARKANSAS
MISSISSIPPI
1.4
NEBRASKA
KANSAS
OKLAHOMA
TEXAS

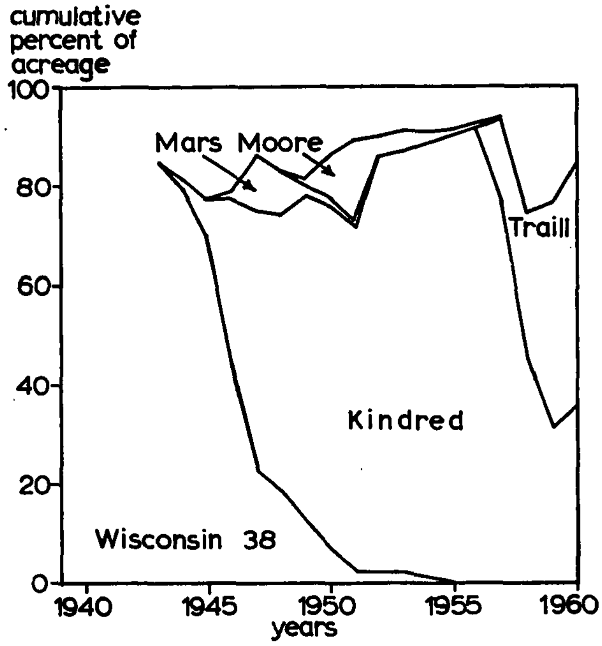


Figure 4.27. Barley variety distribution, two states of the Lake State region, 1943 to 1960

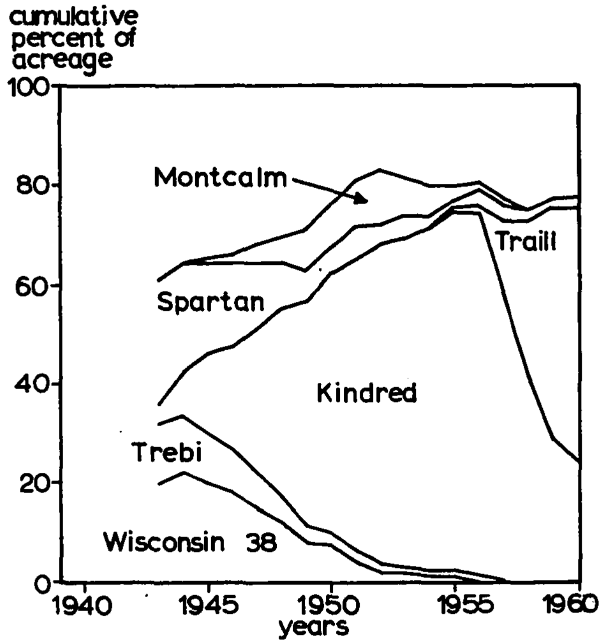


Figure 4.28. Barley variety distribution, three states of the Northern Plains region, 1943 to 1960

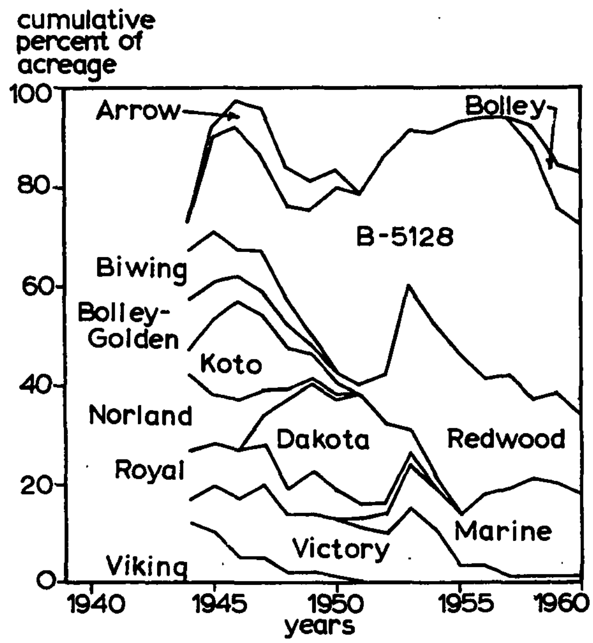


Figure 4.29. Flax variety distribution of Minnesota, Lake State region, 1944 to 1960

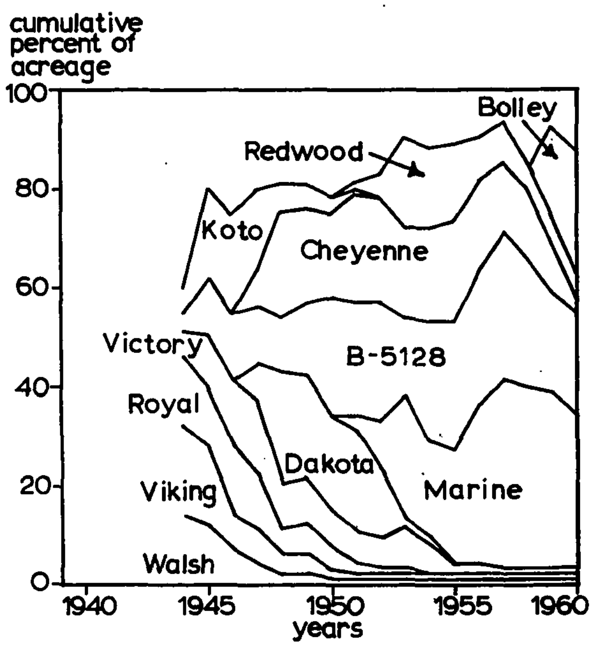


Figure 4.30. Flax variety distribution, two states of the Northern Plains region, 1944 to 1960

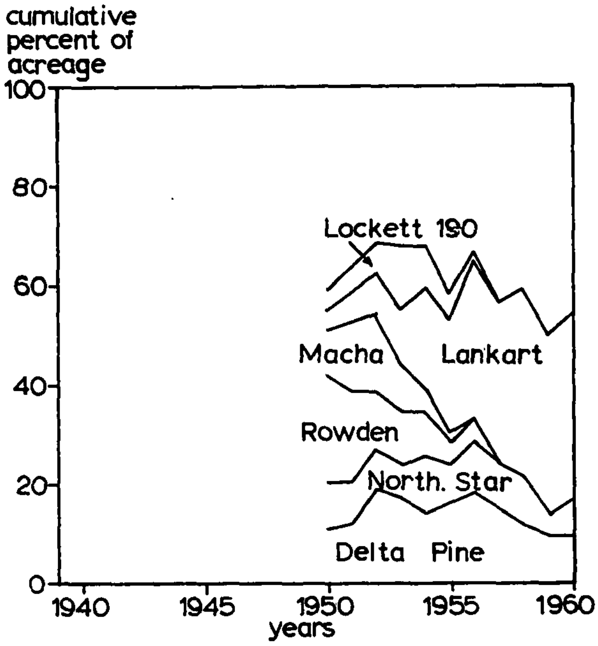


Figure 4.31. Cotton variety distribution, Southern Plains, 1950 to 1960

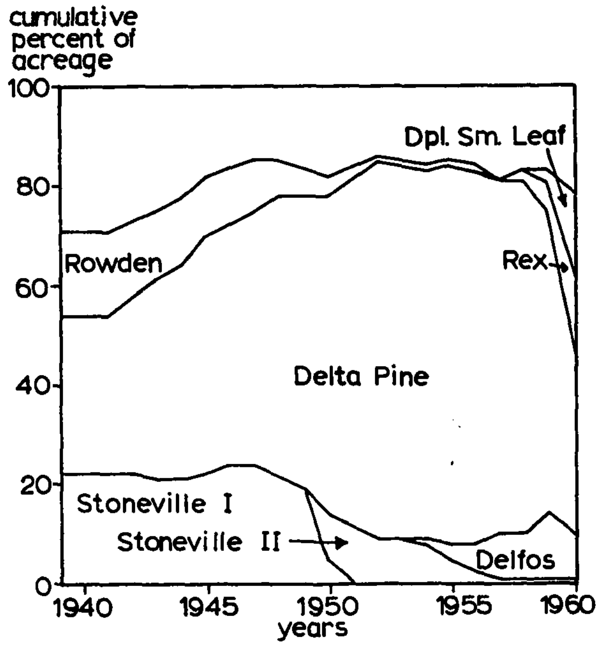


Figure 4.32. Cotton variety distribution, two states of the Delta States region, 1939 to 1960

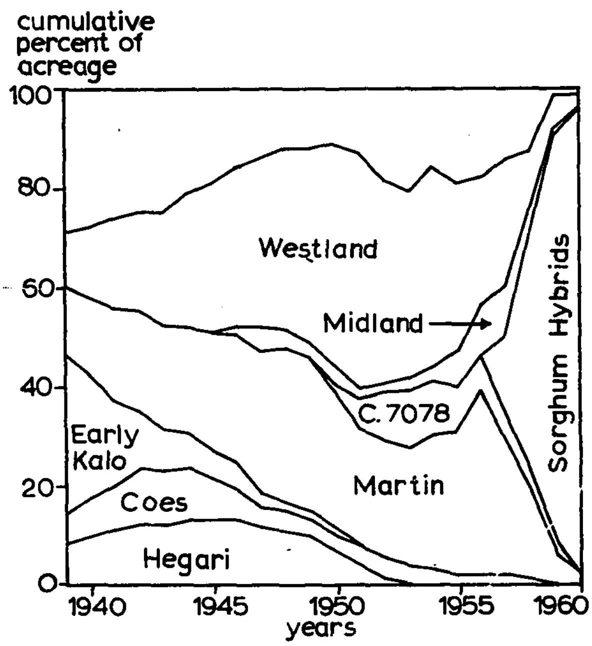


Figure 4.33. Grain sorghum variety distribution, two states of the Northern Plains region, 1939 to 1960

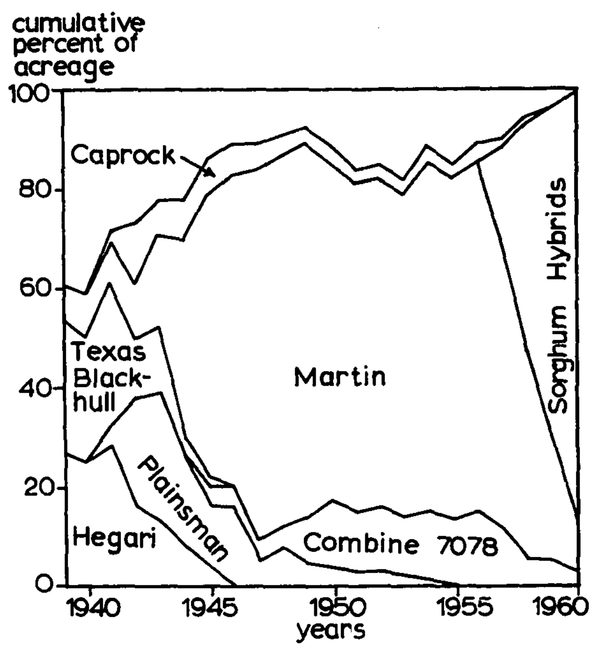


Figure 4.34. Grain sorghum variety distribution, Southern Plains, 1939 to 1960

In spite of these replacements flax variety indices show little progress as evident from Figure 4.24. The flax variety index of North Dakota declined continuously during the last decade because test yields of newly introduced varieties were lower than those of earlier varieties. In view of these results it is not obvious why the newer varieties found widespread acceptance. - Progress of cotton variety indices of Southern Plains and Delta States was more in line with that of other crop varieties. Cotton variety indices of Texas, Arkansas and Mississippi advanced but the Oklahoma index remained at almost the same level as in the forties (Figure 4.25). In both regions variety Delta Pine occupied a major share of the cotton acreage and it was not until recently that varieties superior to the Delta Pine strains were adopted (Figures 4.31 and 4.32).

Grain Sorghum variety indices of four states of the Northern and Southern Plains were very much alike but unique compared to those of other crops. In the Northern Plains states varieties Early Kalo, Hegari and Coes gave way to Westland, Martin, Midland and Combine 7078 (Figure 4.33). Early Kalo, a high yielding grain sorghum variety, was replaced by lower yielding varieties because newer varieties were easier to combine, a factor of importance after changeover from binder to combine harvesting (45, p. 29). In Texas grain sorghum varieties Hegari and Texas Blackhull of the earlier years were inferior in yielding ability to later varieties Martin, Plainsman and Caprock. Correspondingly the Texas sorghum variety index climbed upward during the early period but then remained almost constant as variety Martin became predominant over all others (Figure 4.34). The pattern of the Oklahoma sorghum variety index takes an intermediate position between Kansas and Texas indices (Figure 4.26). Towards the end of the last decade grain sorghum variety indices advanced at an unusually rapid rate reflecting the quick and widespread adoption of sorghum hybrids. In 1957 significant acreages of sorghum hybrids were grown for the first time, by 1960 over eighty percent of the grain sorghum acreage was planted to sorghum hybrids. This rapid rate of adoption surpassed adoption rates of hybrid corn in earlier years.

Hybrid corn Derivation of hybrid corn indices was described in the previous chapter. They were derived from two sets of data: relative yields of corn hybrids over open-pollinated varieties and adoption rates of hybrid corn. Characteristics of estimated regressions of relative corn hybrid yields are listed in Table 4.3. Corresponding yield ratios of corn hybrids over open-pollinated corn varieties (op) are depicted in Figures 4.35 to 4.38. As pointed out in Chapter III relative corn yields were estimated for each state independently. In Figure 4.35 hybrid corn yield ratios of Lake States Minnesota, Wisconsin and Michigan are shown. The 1939 ratios of all three States approximated a 1.20 yield ratio, estimating a 20 percent superiority of hybrid corn yields relative to open-pollinated corn yields. In 1961 yield ratios of all three States were higher, Wisconsin corn hybrids leading with an approximate ratio of 1.50 followed by Michigan and Minnesota estimates near 1.40, indicating 50 and 40 percent higher yields of corn hybrids relative to open-pollinated varieties respectively. Estimates of Corn Belt states for the year 1939 were again very close to the 1.20 ratio but differed in later years (Figure 4.36). In 1961 Iowa's corn hybrid yield ratio of 1.45 was

Table 4.3. Characteristics of linear regressions of relative corn hybrid test yields on years by states

Region	State	Time Period	Coefficients Constant	b	r^2
Lake States	Michigan	1938-61	83.2	.99**	.79
	Wisconsin	1937-61	69.0	1.33**	.83
	Minnesota	1937-61	82.6	.95**	.83
	(Minn. South.)[a]	1937-61	72.8	1.42**	.69
Corn Belt	Ohio	1939-61	116.9	.17-	.05
	Indiana	1937-61	91.4	.67**	.64
	Illinois	1934-61	89.3	.70**	.71
	Iowa	1926-61	78.3	1.09**	.95
	Missouri	1937-61	95.0	.72**	.69
North. Plains	N. Dakota	1944-61	76.5	.55**	.59
	S. Dakota	1937-61	71.5	.93**	.76
	Nebraska	1937-61	79.5	.97**	.83
	Kansas	1939-61	88.8	.67**	.65
South. Plains	Texas	1941-61	88.8	1.07**	.48
	Oklahoma	1943-61	54.1	1.83**	.85
Delta States	Arkansas	1942-61	56.6	1.78**	.73
	Mississippi	1939-61	54.3	1.33**	.81

[a]Regression of relative corn test yields of Southern Minnesota (See Chapter III, p. 49, herein).

**Tested statistically significant at the one percent level of probability.

-Did not test statistically significant at the ten percent level of probability.

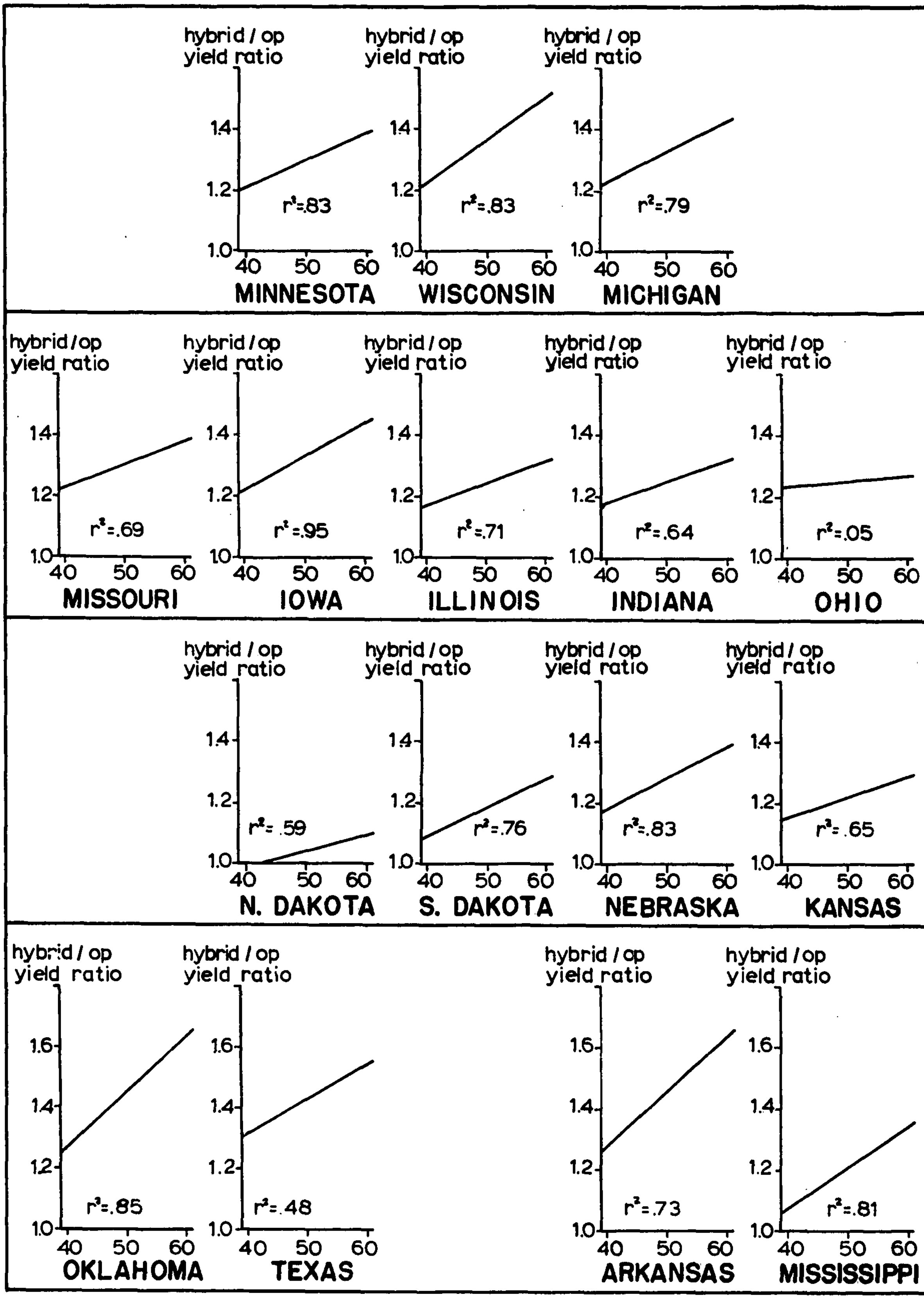
highest among Corn Belt states followed by yield ratios of Missouri, Illinois, Indiana and Ohio. Corresponding ratios of the Northern Plains states were characterized by greater variation (Figure 4.37). The North Dakota ratio did not rise above 1.00 until after 1943 whereas the Nebraska ratio was close to 1.20 in 1939 and very similar to the 1939 ratio of the

Figure 4.35. Corn hybrid yields relative to yields of open-pollinated corn varieties, Lake States, 1939 to 1961

Figure 4.36. Corn hybrid yields relative to yields of open-pollinated corn varieties, Corn Belt States, 1939 to 1961

Figure 4.37. Corn hybrid yields relative to yields of open-pollinated corn varieties, Northern Plains States, 1939 to 1961

Figure 4.38. Corn hybrid yields relative to yields of open-pollinated corn varieties, Southern Plains and Delta States (excl. Louisiana), 1939 to 1961


hybrid / op
yield ratio
MINNESOTA
r²=.83
WISCONSIN
r²=.83
MICHIGAN
r²=.79
MISSOURI
r²=.69
IOWA
r²=.95
ILLINOIS
r²=.71
INDIANA
r²=.64
OHIO
r²=.05
N. DAKOTA
r²=.59
S. DAKOTA
r²=.76
NEBRASKA
r²=.83
KANSAS
r²=.65
OKLAHOMA
r²=.85
TEXAS
r²=.48
ARKANSAS
r²=.73
MISSISSIPPI
r²=.81
1.0
1.2
1.4
1.6
40
50
60

neighboring State Iowa. By 1961 Nebraska was leading Northern Plains states with an approximate ratio of 1.4, indicative of a 40 percent yield superiority of hybrid corn. Yield ratios of hybrid corn in the Southern Plains and Delta States were almost identical for Oklahoma and Arkansas but unusually high (Figure 4.38). Both indices started out at 1.25 ratios in 1939 and ended up at ratios near 1.65 in 1961. By contrast Texas and Mississippi had lower corn yield ratios. From 1939 to 1961 the Texas ratio increased from 1.31 to 1.54 and the Mississippi ratio increased from 1.06 to 1.35 over the same years. In Figures 4.35 to 4.38 r^2-values for some regression estimates are greater than others, low values for Ohio, Indiana, North Dakota, Kansas and Texas being indicative of greater dispersion of actual ratios about the estimated ratios. With exception of the Ohio coefficient all correlation coefficients tested significant at the one percent level.

Annual adoption rates of hybrid corn are shown in Figures 4.39 to 4.42 in terms of percent of acreage planted to hybrid corn. Hybrid corn was most rapidly adopted in the Corn Belt and the Lake States. Adoption of hybrid corn in the Northern Plains states, particularly in North Dakota, was slower with the exception of Nebraska where the adoption rate was similar to those of Iowa and Missouri. Adoption rates of the Southern Plains and Delta States lagged behind those of other regions and even in 1961 part of the acreage was still planted to open-pollinated corn varieties.

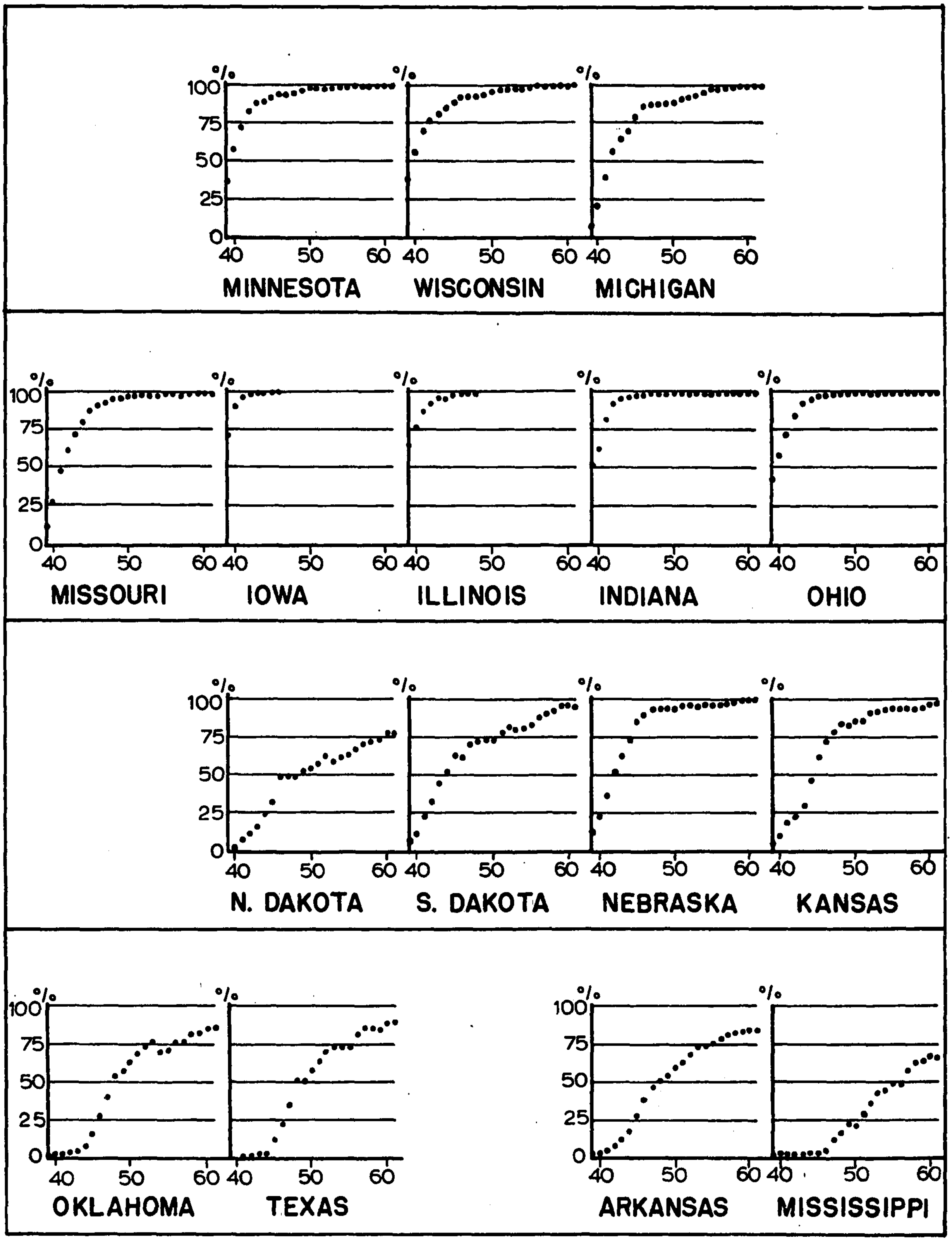
Annual corn hybrid indices of individual States are shown in Figures 4.43 to 4.46. Corn hybrid indices of the Lake States advanced more

Figure 4.39. Percentage of state corn acreage planted with hybrid seed, Lake States, 1939 to 1961

Figure 4.40. Percentage of state corn acreage planted with hybrid seed, Corn Belt States, 1939 to 1961

Figure 4.41. Percentage of state corn acreage planted with hybrid seed, Northern Plains States, 1939 to 1961

Figure 4.42. Percentage of state corn acreage planted with hybrid seed, Southern Plains and Delta States (excl. Louisiana), 1939 to 1961


%
100
75
50
25
0
40
50
60
MINNESOTA
WISCONSIN
MICHIGAN
MISSOURI
IOWA
ILLINOIS
INDIANA
OHIO
N. DAKOTA
S. DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
ARKANSAS
MISSISSIPPI

rapidly during earlier years than later. During the earlier period indices advanced due to adoption of corn hybrids as well as introduction of improved hybrids. Once all of the corn acreage was planted to hybrid corn additional increases could only come from replacement of older by newer and higher yielding corn hybrids. In the Lake States and in the Corn Belt region practically all corn acreage was in hybrid corn by 1949 therefore the general decline in rates of advance of corn hybrid indices during the fifties. In Nebraska corn hybrids were adopted sooner than in other states of the Northern Plains region which explains the more rapid rise of the Nebraska index during earlier years. Corn hybrid indices of Southern Plains and Delta States progressed most rapidly because relative test yields of hybrid corn advanced more than in other states and adoption rates were highest during the late forties and early fifties. Even though relative corn hybrid yield ratios of these states were unusually high one may expect a lower bushel increase than in Corn Belt states where, for years, corn yields have been much higher than in Southern Plains and Delta States. However, the impact of superior hybrids and other crop varieties on crop yields can only be quantified if other yield increasing technologies are taken into account.

Fertilizer Application Rates

Rates of nutrient application were estimated according to procedures outlined in Chapter III. In Figures 4.47 to 4.51 estimated application rates (in terms of total plant nutrients) are shown annually for the years 1939 to 1960 by major crops and production regions. For regional aggregation state application rates were weighted by state crop acreages.

Figure 4.43. Annual corn hybrid indices, Lake States, 1939 to 1961

Figure 4.44. Annual corn hybrid indices, Corn Belt States, 1939 to 1961

Figure 4.45. Annual corn hybrid indices, Northern Plains States, 1939 to 1961

Figure 4.46. Annual corn hybrid indices, Southern Plains and Delta States (excl. Louisiana), 1939 to 1961

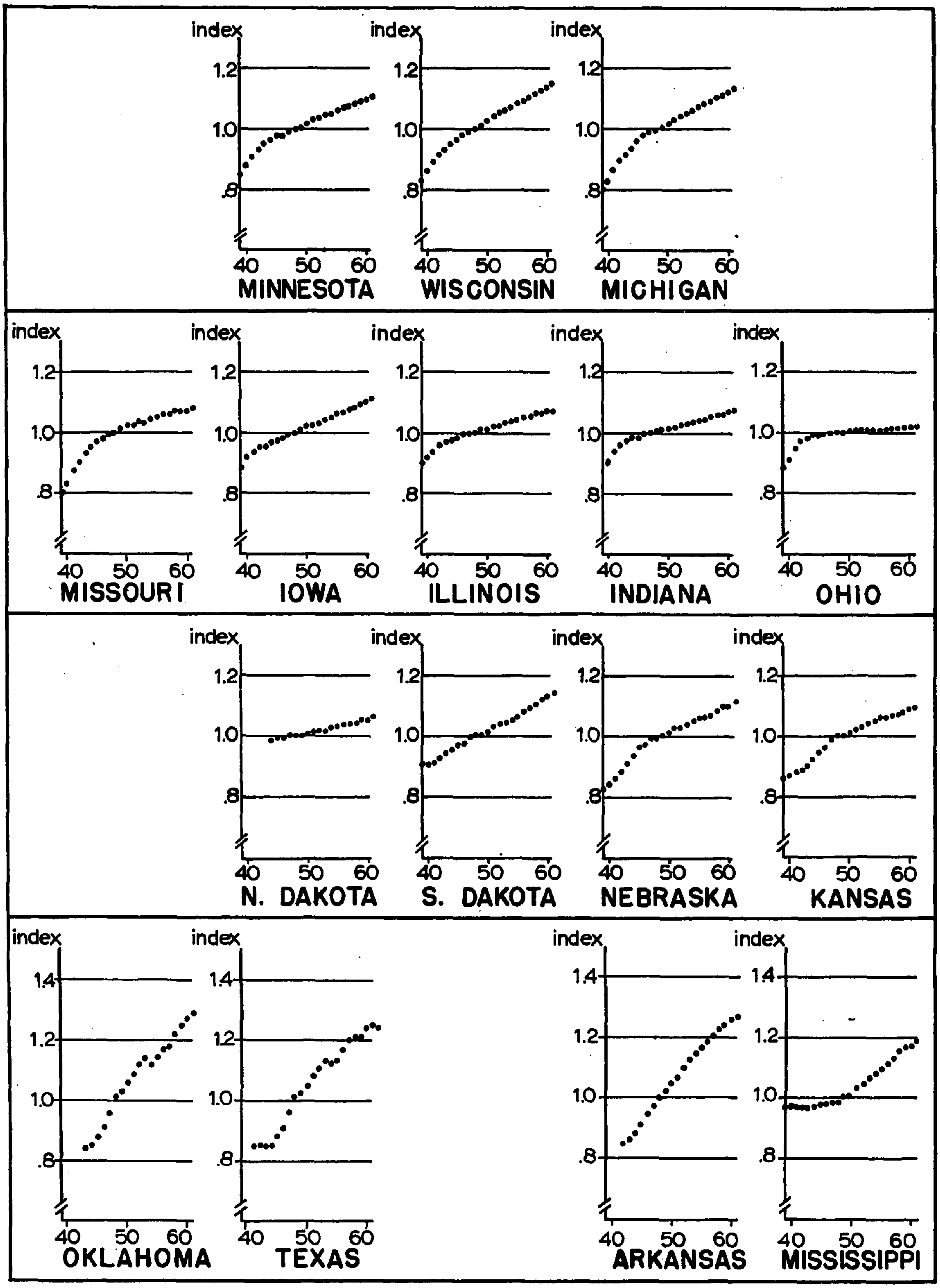
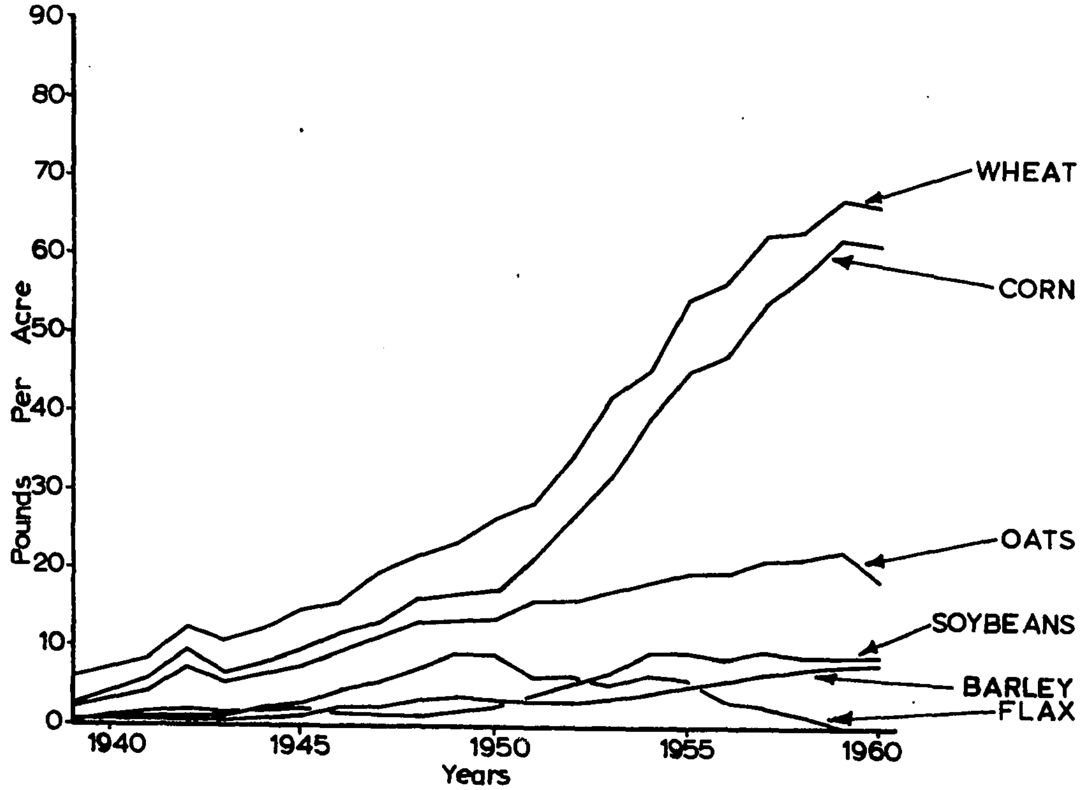

index
1.2
1.0
.8
40 50 60
MINNESOTA
WISCONSIN
MICHIGAN
MISSOURI
IOWA
ILLINOIS
INDIANA
OHIO
N. DAKOTA
S. DAKOTA
NEBRASKA
KANSAS
1.4
OKLAHOMA
TEXAS
ARKANSAS
MISSISSIPPI

Figure 4.47. Estimated annual nutrient application per acre of major crops, Lake States, 1939 to 1960

Figure 4.48. Estimated annual nutrient application per acre of major crops, Corn Belt, 1939 to 1960


90
80
70
60
50
40
30
20
10
0
Pounds Per Acre
1940
1945
1950
1955
1960
Years
WHEAT
CORN
OATS
SOYBEANS
BARLEY
FLAX

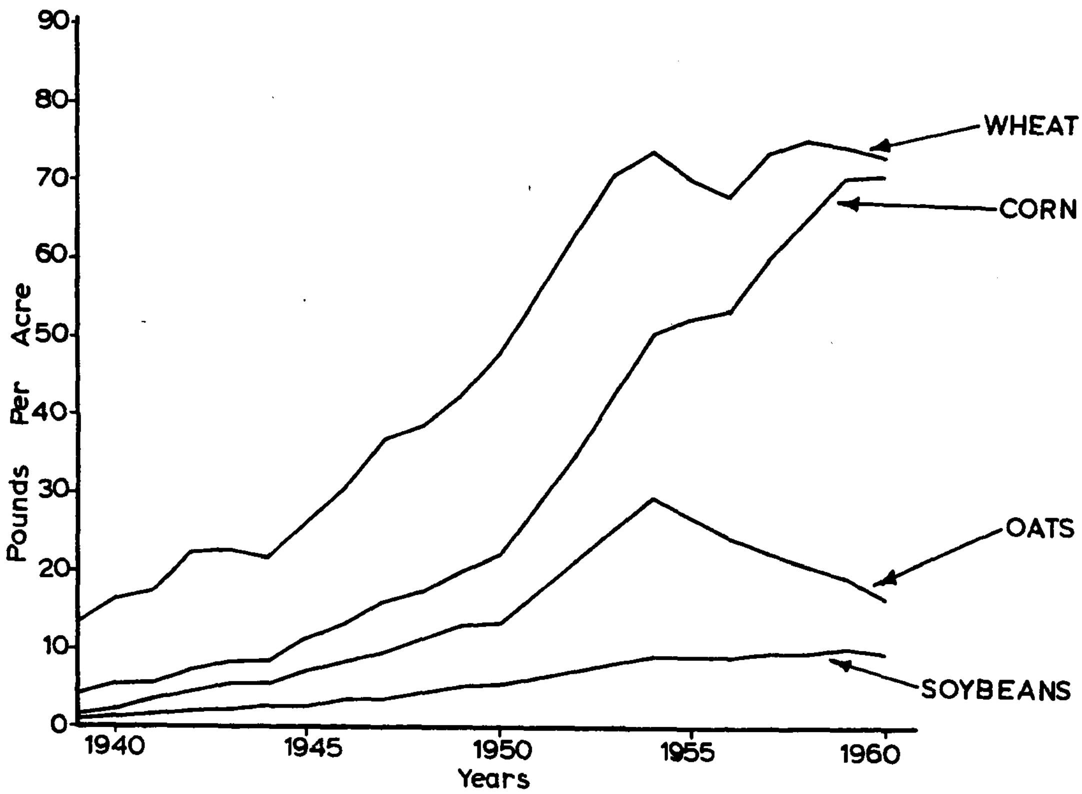
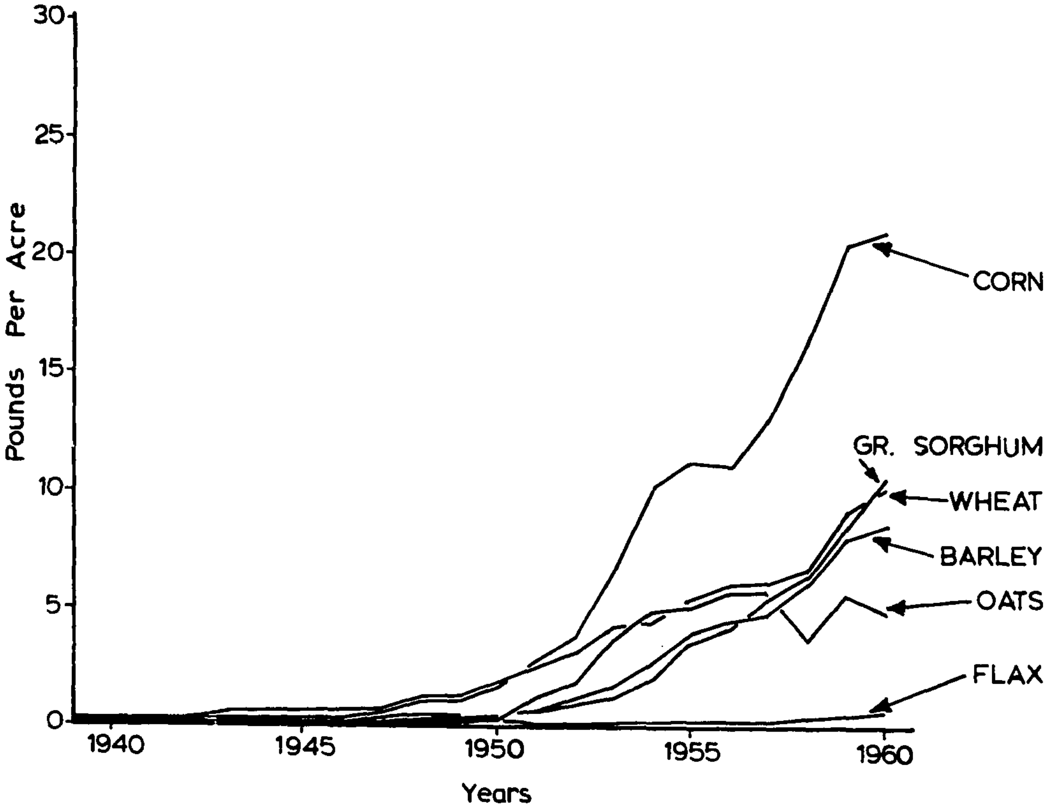
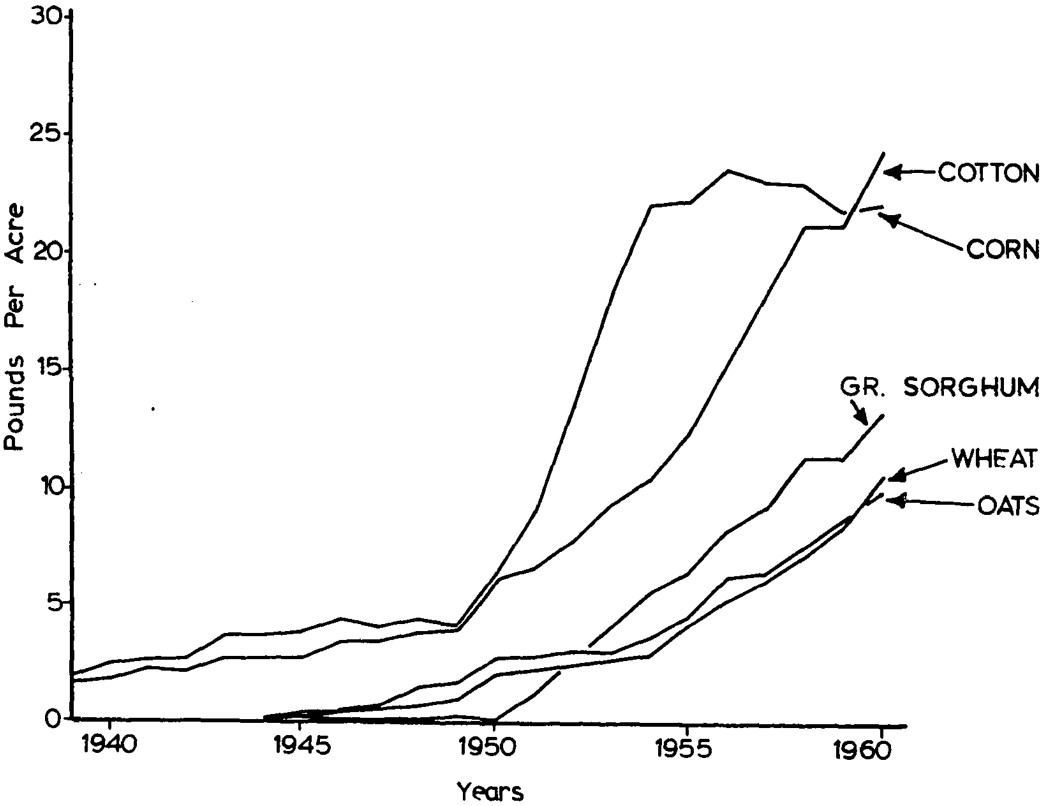

90
80
70
60
50
40
30
20
10
0
Pounds Per Acre
1940
1945
1950
1955
1960
Years
WHEAT
CORN
OATS
SOYBEANS

Figure 4.49. Estimated annual nutrient application per acre of major crops, Northern Plains, 1939 to 1960

Figure 4.50. Estimated annual nutrient application per acre of major crops, Southern Plains, 1939 to 1960


30
25
20
15
10
5
0
Pounds Per Acre
1940
1945
1950
1955
1960
Years
CORN
GR. SORGHUM
WHEAT
BARLEY
OATS
FLAX


30
25
20
15
10
5
0
Pounds Per Acre
1940
1945
1950
1955
1960
Years
COTTON
CORN
GR. SORGHUM
WHEAT
OATS

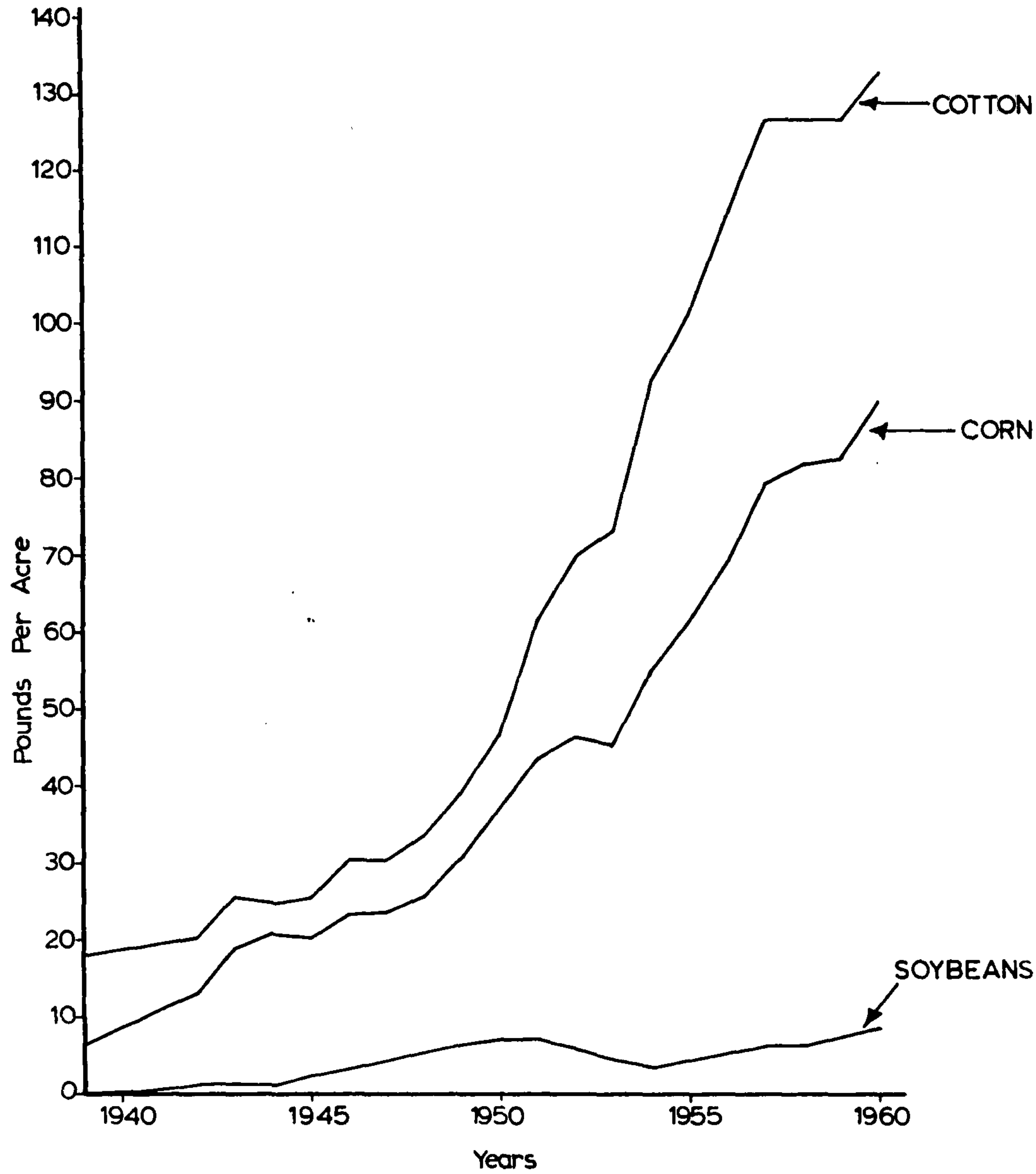


Figure 4.51. Estimated annual nutrient application per acre of major crops, Delta States, 1939 to 1960

Estimated fertilizer application rates of individual States and crops are tabulated in Appendix C. As illustrated in Figure 4.47 all major crops of the Lake States received fertilizer over the last two decades. Application rates of wheat and corn were highest, followed by oats, soybeans, barley and flax at much lower levels. Fertilizer application rates were heavier in the eastern part of the Lake States than in the west, e.g., Michigan rates on corn and wheat were nearly twice as high as Minnesota rates. In Minnesota and Wisconsin farmers applied more fertilizer to corn than wheat throughout the period, while Michigan application rates to corn did not exceed wheat application rates until 1961. Corn Belt rates followed a somewhat similar pattern, wheat and corn received the heaviest application, oats and soybeans received less (Figure 4.48). Again fertilization rates were highest in the east and declined towards the west. For example in 1961 Ohio farmers used more than twice as much fertilizer per acre of corn as Iowa farmers did. Application rates in Missouri were higher taking an intermediate position between Iowa and Delta States. In Missouri application rates of all crops increased steadily. In other Corn Belt states fertilizer use on soybeans has levelled off in recent years and oats received less fertilizer in 1960 than five years earlier. In accordance with the general east-west trend, application rates in the Northern Plains states were much lower than in Lake and Corn Belt states. Application rates of major crops in the Northern Plains are pictured in Figure 4.49 where scales of the vertical axis (pounds of N+P+K) are drawn three times as large as for other regions. With the exception of North Dakota, corn received the heaviest rates of application in all states. Wheat, barley, grain sorghum and oats received lower rates but fertilizer application to grain sorghums gained relative to other crops in recent years, especially in Nebraska. In the Southern Plains fertilizer use was comparatively low. Corn and cotton were fertilized heavier than grain sorghum, oats and wheat, but grain sorghum rates gained relative to corn rates. Fertilizer was used extensively in the Delta States (Figure 4.51). Application to cotton and corn more than doubled during the last decade and was estimated at 135 and 89 pounds per acre of cotton and corn respectively in 1960. Soybeans, by contrast, received less than 10 pounds per acre which corresponds to soybean fertilizer application in most other states. Rates of fertilizer use on other crops are listed in Appendix C. As a rule fertilizer use on hay, pasture and legumes was low and high for special crops such as potatoes, sugarbeets, sugarcane and rice.

Fertilizer Response

In order to avoid the problem of multicollinearity regression coefficients of individual plant nutrients were derived for each crop and state on the basis of prior knowledge. Information on crop fertilizer response, collected by the Fertilizer Work Group of the National Soil and Fertilizer Research Committee, was used as data source (46). This data collection consisted of a nation wide summary of state fertilizer response data which were estimates of changes in state crop yields due to varying rates of nutrient application. For derviation of these estimates the following procedure was followed:

> "All pertinent published and unpublished field fertilizer data through 1950 were summarized by principal crops, usually according to soils or geographic regions within a State. Yield response data then were selected for individual nutrients where yields were not limited by lack of other nutrients. From these, weighted summary curves (Form A response curves) were prepared on a statewide basis for each principal crop....The Form A curves thus were a close expression of the data from field experiments.
>
> "The Form A curves from each State usually were reviewed by all of the State representatives within a region. This review frequently showed inconsistencies within the curves or omissions of certain crops and nutrients. In order to present a complete picture, the inconsistencies were corrected and gaps filled by making a second set of curves called Form B curves. The Form B curves thus were based on available data, plus experience, observations, and combined judgment of the technical specialists of the State and region. Where experimental data were adequate, the Form A and Form B curves were interchangeable. In some States where data on particular crops were lacking Form B curves for parallel situations elsewhere were used to complete the tables" (46, p. 1).

In this summary fertilizer response was presented by crops and states in terms of (1) estimated average yields from given application rates and (2) estimated percentage changes in yields resulting from variation of N-P-K application rates, on 1950 basis. In order to determine regression coefficients which could be readily incorporated into state crop production functions the crop yield response to individual nutrients was estimated first. Then estimated coefficients were adjusted for quantification of combined nutrient response.

For estimating response coefficients of individual nutrients one-variable equations, linear in the logarithms, were fitted to response data. The procedure of estimation may be illustrated by use of corn nutrients response data of Indiana. In Table 4.4 estimated average yield of corn with given N-P-K application rates is shown, in Table 4.5 estimated percentage changes in yields resulting from increases or decreases from average N-P-K application rates are tabulated. Data in Table 4.6 were derived by combining information of Tables 4.4 and 4.5 into yields per acre and corresponding rates of N-P-K application. Data in Table 4.6 were then used to estimate relative corn yield response to varying rates of nutrient application. Relative corn yield response is defined by equation 4.7 where corn yield Y_i corresponds to a nutrient application of

$$Y_i \,/\, Y_o \;=\; (X_i + 1.0)^b \tag{4.7}$$

X_i pounds per acre, Y_o is the base yield attained without nutrient application and b is the regression coefficient to be estimated. If the rate of nutrient application is zero relative corn yield response equals 1.00, if the rate is greater than zero response is greater than 1.00. Thus yield response to nutrient application is expressed by ratio of crop yields <u>with</u> nutrient application over crop yield <u>without</u> nutrient application. Since the data sets served merely to reconstruct the original Form A response curves it could be assumed that all b-coeﬀicients would be positive. To estimate regression coefficients of individual nutrients, logarithms of the Y_i/Y_o ratios were regressed linearly on logarithms of the coded application rates $(X_i + 1.0)$ by least square regression method. In conformance with equation 4.7 regression lines were forced through the origin so that relative yield response ratios equaled 1.00 if no fertilizer was applied. The estimated b-coefficients, denoted by n, p, k for N, P, K response functions, are tabulated in Table 4.7. As an indication of the goodness of fit coefficients of determination or r^2 values are listed (47, p. 180). They can be expected to range from zero to unity where zero would imply minimum and unity maximum correlation between

Table 4.4. Estimated average corn yield from given application rates of N, P and K, Indiana, 1950 basis[a]

Rate of N-P-K Application Pounds/Acre	Estimated Corn Yield N Bu./Acre	P Bu./Acre	K Bu./Acre
120	82	-	82
80	78	82	81
40	68	77	76
20	63	70	69
10	59	60	64
0	52	43	59
Ave. Use[b]	57	70	68

[a]Source: (46, p. 32).

[b]Average use refers to average state use, basis 1950. It was estimated at 6, 22 and 19 pounds of N, P and K respectively.

Table 4.5. Estimated percentage change in corn yield resulting from increases or decreases from average application rates of N, P, and K, Indiana, 1950 basis[a]

Change in Application Rate %	Percentage change in Corn Yield N %	P %	K %
+200	+9	+16	+15
+100	+4	+11	+10
+ 50	+2	+ 6	+ 5
+ 25	+1	+ 4	+ 2
+ 10	.3	+ 1	+ 1
Ave. Use[b]	0	0	0
- 10	- .9	- 2	- 1
- 25	-2	- 6	- 4
- 50	-3	-12	- 7
-100	-8	-38	-15

[a]Source: (46, p. 32).

[b]Average use refers to average state use, basis 1950. It was estimated at 6, 22 and 19 pounds of N, P and K respectively.

Table 4.6. Estimated average corn yield from varying rates of N, P and K application, Indiana, 1950 basis[a]

Rate of Application		Estimated Yield and Application Rates					
		Yield	N-Rate	Yield	P-Rate	Yield	K-Rate
%	Lbs./Acre	Bu./Acre	Lbs./Acre	Bu./Acre	Lbs./Acre	Bu./Acre	Lbs./Acre
	120	82.0	120.0			82.0	120.0
	80	78.0	80.0	82.0	80.0	81.0	80.0
	40	68.0	40.0	77.0	40.0	76.0	40.0
	20	63.0	20.0	70.0	20.0	69.0	20.0
	10	59.0	10.0	60.0	10.0	64.0	10.0
+200		62.1	18.0	81.2	66.0	78.2	57.0
+100		59.3	12.0	77.7	44.0	74.8	38.0
+ 50		58.1	9.0	74.2	33.0	71.4	28.5
+ 25		57.6	7.5	72.8	27.5	69.4	23.8
+ 10		57.2	6.6	70.7	24.2	68.7	20.9
Ave. Use							
0		57.0	6.0	70.0	22.0	68.0	19.0
- 10		56.5	5.4	68.6	19.8	67.3	17.1
- 25		55.9	4.5	65.8	16.5	65.3	14.2
- 50		55.3	3.0	61.6	11.0	63.2	9.5
-100		52.4	0	43.4	0	57.8	0

[a]Derived from estimates of Tables 4.4 and 4.5 herein.

original (handdrawn curves) and regression estimates. Most r^2-values ranged from .80 to .99 as shown in Table 4.7. In addition the number of observations (No.) is shown. In some cases, where crop nutrient response data were lacking, coefficients were inserted as described in footnotes of Table 4.7.

Regression coefficients of single nutrient response functions required adjustments before they could be inserted in state crop production functions. Single nutrient response coefficients of Table 4.7 were valid if response to nutrient was not limited by lack of others. In practice farmers apply fertilizer mixtures containing two or three nutrients because response to any one nutrient usually is limited by lack of others. For

Table 4.7. Characteristics of estimated N-P-K response functions by crops and states

		N-Functions			P-Functions			K-Functions		
Crop	State	n	r^2	No.	p	r^2	No.	k	r^2	No.
Wheat	Mich.	.077	.89	15	.180	.98	15	.049	.96	15
	Wisc.	.054	.92	10	.182	.98	15	.049	.96	15
	Minn.	.035	.85	9	.037	.89	13	.012	.92	14
	Ohio	.116	.94	13	.192	.98	14	.081	.99	13
	Ind.	.149	.97	14	.247	.99	12	.056	.98	14
	Ill.	.083	.85	16	.058	.78	16	.034	.75	16
	Iowa	.090	.94	9	.036	.96	14	.000	-	0
	Mo.	.074	.88	13	.199	.99	14	.019	.88	13
	N. Dak.	.000	-	0	.056	.96	8	.000	-	0
	S. Dak.	.136	.94	5	.066	.89	5	.000	-	0
	Nebr.	.080	.99	7	.045	.98	6	.000	-	0
	Kans.	.069	.95	14	.037	.93	13	.031	.98	7
	Texas	.100	.97	6	.042	.99	6	.000	-	0
	Okla.	.203	.99	6	.157	.86	13	.000	-	0
Oats	Mich.	.076	.94	11	.054	.91	15	.041	.96	13
	Wisc.	.084	.87	16	.100	.87	16	.061	.89	16
	Minn.	.075	.98	6	.043	.88	14	.006	.96	10
	Ohio	.083	.83	14	.102	.95	14	.058	.97	13
	Ind.	.073	.88	15	.048	.99	14	.006	.88	14
	Ill.	.156	.95	11	.094	.79	16	.016	.82	16
	Iowa	.043	.86	13	.029	.91	13	.002	.46	8
	Mo.	.185	.88	14	.078	.92	15	.011	.74	13
	N. Dak.	.075[a]	-	0	.043[a]	-	0	.006[a]	-	0
	S. Dak.	.084	.93	5	.000	-	0	.000	-	0
	Nebr.	.072[b]	-	0	.019[b]	-	0	.000	-	0
	Kans.	.061	.89	14	.038	.81	13	.000	-	0
	Texas	.086	.93	8	.033	.99	7	.030	.97	6
	Okla.	.199	.99	6	.132	.84	13	.002	.63	9
Soybeans	Mich.	.049	.95	11	.042	.93	15	.048	.93	15
	Wisc.	.000	-	0	.043	.85	15	.060	.92	15
	Minn.	.000[c]	-	0	.033[c]	-	0	.035[c]	-	0

[a]Minn. coefficient.

[b]Average of S. Dak and Kans. coefficients

[c]Average of Iowa and Wisc. coefficients

Table 4.7 (Continued)

Crop	State	N-Functions n	r^2	No.	P-Functions p	r^2	No.	K-Functions k	r^2	No.
Soybeans	Ohio	000	-	0	.043	.88	14	.055	.96	14
	Ind.	.009	.90	9	.021	.96	13	.026	.82	15
	Ill.	.031	.94	9	.077	.96	11	.080	.92	11
	Iowa	000	-	0	.023	.95	7	.010	.96	6
	Mo.	.026	.90	6	.021	.90	9	000	-	0
	Ark.	000	-	0	.052	.87	14	.027	.85	13
	Miss.	000	-	0	.013	.97	13	.012	.95	14
	La.	000	-	0	.026	.87	13	.016	.98	9
Barley	Minn.	.044	.96	6	.033	.96	15	.006	.78	10
	N. Dak.	000	-	0	.045	.93	8	000	-	0
	S. Dak.	.141	.91	6	.053	.93	6	000	-	0
	Nebr.	.100[b]	-	0	.056[b]	-	0	000[b]	-	0
	Kans.	.059	.91	10	.060	.95	8	000	-	0
Flax	Minn.	.084	.95	8	.097	.84	14	.049	.94	14
	N. Dak.	.136[d]	-	0	.120[d]	-	0	.025[d]	-	0
	S. Dak.	.188	.97	5	.143	.95	7	000	-	0
Cotton	Texas	.027	.79	13	.017	.84	13	.023	.98	8
	Okla.	.061	.92	9	.035	.84	13	.045	.99	9
	Ark.	.089	.95	13	.009	.79	13	.073	.98	13
	Miss.	.098	.98	11	.025	.96	13	.016	.94	13
	La.	.128	.98	14	.067	.92	13	.043	.81	13
Gr. Sorghum										
	Nebr.	.085[e]	-	0	.026[e]	-	0	000[e]	-	0
	Kans.	.085	.95	6	.026	.96	5	000	-	0
	Texas	.084	.96	6	.025	.96	5	.026	.96	5
	Okla.	.084[f]	-	0	.025[f]	-	0	.026[f]	-	0
Corn	Mich.	.039	.84	14	.031	.95	14	.037	.96	14
	Wisc.	.099	.85	16	.110	.90	16	.132	.92	16
	Minn.	.056	.92	9	.036	.81	15	.019	.87	14
	Ohio	.109	.89	16	.165	.98	16	.046	.85	15
	Ind.	.068	.92	15	.150	.99	14	.064	.97	15
	Ill.	.090	.83	16	.052	.90	16	.049	.88	16
	Iowa	.029	.91	14	.021	.94	14	.013	.82	13
	Mo.	.129	.79	15	.080	.84	16	.029	.81	14

[d]Average of Minn. and S. Dak. coefficients.

[e]Kans. coefficient.

[f]Texas coefficient.

Table 4.7 (Continued)

Crop	State	N-Functions n	r^2	No.	P-Functions p	r^2	No.	K-Functions k	r^2	No.
Corn	N. Dak.	.072	.78	14	.029	.89	13	000	-	0
	S. Dak.	.082	.86	6	.055	.98	12	000	-	0
	Nebr.	.065	.92	14	000	-	0	000	-	0
	Kans.	.142	.97	8	000	-	0	.028	.91	5
	Texas	.088	.84	14	.045	.78	14	.009	.92	7
	Okla.	.037	.67	13	.031	.74	14	.012	.98	13
	Ark.	.184	.93	15	.050	.93	12	.133	.96	12
	Miss.	.176	.94	15	.030	.85	13	.015	.89	13
	La.	.141	.89	15	.030	.85	13	.025	.77	13
Tame Hay	Mich.	000	-	0	.104	.95	15	.098	.95	15
	Wisc.	.155	.92	9	.088	.91	12	.131	.93	12
	Minn.	000	-	0	.078	.77	14	.027	.96	14
	Ohio	000	-	0	.105	.77	15	.142	.92	16
	Ind.	.045	.95	8	.108	.83	16	.157	.87	16
	Ill.	.141	.86	7	.206	.99	16	.132	.80	7
	Iowa	.038	.87	8	.065	.87	14	.004	.47	6
	Mo.	.138	.90	8	.238	.92	16	.101	.91	11
	N. Dak.	000	-	0	.060	.81	13	000	-	0
	S. Dak.	.044	.86	6	.065	.87	7	000	-	0
	Nebr.	000	-	0	.033	.80	13	000	-	0
	Kans.	.145	.87	15	.042	.97	13	.061	.89	14
	Texas	.095	.91	14	.092	.98	14	000	-	0
	Okla.	000	-	0	.141	.99	12	000	-	0
	Ark.	.087	.81	14	.119	.94	13	.082	.88	14
	Miss.	000	-	0	.065	.94	13	000	-	0
	La.	.096	.94	9	.111	.95	14	.166	.96	14

estimating nutrient response of fertilizer mixtures it was assumed that combined nutrient response could be neither greater than maximum nor smaller than minimum response of any one nutrient. This assumption was justifiable because estimated maximum yield response, characterized by the highest b-coefficient among the N, P and K response functions, could be attained only if other nutrients were plentiful. Conversely combined nutrient response could not be smaller than response to the least productive nutrient as defined by the lowest b-coefficient because application of more productive nutrients could not reduce response below that of the least productive nutrient. A function of combined nutrient response which satisfies these assumptions is 4.8 where the ratio Y/Y_o represents esti-

$$Y/Y_o = (N+1.0)^{\frac{n^2}{(n+p+k)}} (P+1.0)^{\frac{p^2}{(n+p+k)}} (K+1.0)^{\frac{k^2}{(n+p+k)}} \qquad (4.8)$$

mated relative yield response to application of nutrient mix, letters N, P and K are application rates of nitrogen, phosphoric oxide and potash, and n, p, k denote the corresponding coefficients which are listed in Table 4.7. Exponents of equation 4.8 are the same as those of single nutrient functions except that they are weighted by respective ratios of individual exponents over the sum of exponents. If, in function 4.8, rates of N, P and K application are identical the combined nutrient response can be neither greater nor smaller than maximum or minimum response of individual nutrients. Corn yield response to single nutrients was estimated for Indiana by n, p, k coefficients .068, .150 and .064 respectively as indicated in Table 4.7. Combined nutrient response of Indiana corn to N-P-K application was estimated according to 4.8 by 4.9. The sum of the three coefficients in 4.10 amounts to 0.111, it represents the coefficient of combined nutrient response and is smaller than .150 and larger than .064, the maximum and minimum values of the coefficients of

$$Y/Y_o = (N+1.0)^{\frac{.068^2}{.282}} (P+1.0)^{\frac{.150^2}{.282}} (K+1.0)^{\frac{.064^2}{.282}} \tag{4.9}$$

$$Y/Y_o = (N+1.0)^{.016}(P+1.0)^{.080} (K+1.0)^{.015} \tag{4.10}$$

single nutrient functions. In some cases response to a single nutrient was zero. For example response to N, P, K application to soybeans in Iowa was estimated at .000, .023 and .010 respectively. In accordance with adjustment formula 4.8 the combined nutrient response function becomes 4.12 which follows from 4.11. If Iowa farmers applied nitrogen

$$Y/Y_o = (N+1.0)^{\frac{.000}{.033}} (P+1.0)^{\frac{.023}{.033}} (K+1.0)^{\frac{.101}{.033}} \tag{4.11}$$

$$Y/Y_o = (P+1.0)^{.016} (K+1.0)^{.003} \tag{4.12}$$

to soybeans no yield increase was computed, if they did not apply nitrogen function 4.12 did not discount against it. In this fashion adjustment formula 4.8 was employed to accommodate use or non-use of nutrients in case of single nutrient, zero-response functions. After adjusting all N, P, K response coefficients of Table 4.7 nutrient response was incorporated in the state crop production function analysis.

State crop production functions were estimated according to procedures outlined at the beginning of this chapter. As a first step annual state crop yields values were deflated by estimated variety indices and annual nutrient response values. Then logarithms of annual deflated yields were regressed on logarithms of annual acreage indices, weather indices and a time trend variable as indicated by 4.13 to 4.15 where Y'

$$Y' = Y/V \cdot (N+1.0)^{n'} \cdot (P+1.0)^{p'} \cdot (K+1.0)^{k'} \qquad (4.13)$$

$$Y_1' = b_1' + a'A_1 + w'W_1 + t'T_1 + e'_1 \qquad (4.14)$$

$$Y = b' \cdot V \cdot (N+1.0)^{n'} \cdot (P+1.0)^{p'} \cdot (K+1.0)^{k'} \cdot A^{a'} \cdot W^{w'} \cdot T^{t'} \cdot e' \qquad (4.15)$$

is the deflated state crop yield, Y is state crop yield, V is variety index, N, P and K are application rates of nitrogen, phosphoric oxide and potash respectively, A is acreage index, W is weather index and T is time in years, b' is a constant and e' refers to the error term. All variables and coefficients with subscript 1 are logarithms. Regression coefficients b', n', p', k', a', w', t' as well as the error term e' were expected to differ from the usual least square regression estimates because coefficients based on a priori knowledge were incorporated in the estimating equation.

Estimated regression coefficients of 86 state crop production functions are shown in Table 4.8. Also corresponding correlation indices or r^2 values are listed; they measure correlations between actual state crop yields and yields estimated by the postulated regressions (47, p.188). The frequency distributions of these R^2 values are stratified by frequency intervals and crops and tabulated in Table 4.9. Most R^2 values fell in the .80 to .89 interval, only four R^2 values were in the .90 to .99 range and all others were in lower valued intervals. There appeared to be significant differences between crops. Average R^2 values were lowest for production function estimates of flax, barley and oats, they were in the intermediate range for estimates of soybeans, wheat, cotton and tame hay

Table 4.8. Characteristics of estimated state crop production functions by crops and states

	Regression Coefficients								
Crop State	Con- stant[a]	N+1.0	P+1.0	K+1.0	Acreage Index	Weather Index	Net Time Trend	R^2	Years
Wheat									
Mich.	17.6	.019	.106	.008	.192+	.267*	.057	.80	39-60
Wisc.	18.1	.010	.117	.008	-.173	.171+	.400	.60	42-60
Minn.	17.0	.015	.016	.002	.005	.543**	-.121	.89	29-60
Ohio	15.5	.035	.095	.017	.040	.104	.253	.42	39-60
Ind.	12.8	.049	.135	.007	-.107	.563**	.254	.82	39-60
Ill.	19.6	.039	.019	.007	.032	.475**	.291**	.81	29-60
Iowa	19.8	.064	.011	.000	.013	.594**	.096	.68	27-60
N. Dak. (S)[b]	13.2	.000	.056	.000	-.248	.599**	.467**	.82	29-60
S. Dak. (S)	11.0	.092	.022	.000	-.052	.546**	.209		31-60
S. Dak. (W)[c]	15.8	.092	.022	.000	.440*	.225*	1.237**	.69	31-60
Nebr. (S)	12.1	.051	.016	.000	-.113	.441**	.131	.53	29-60
Nebr. (W)	19.5	.051	.016	.000	.073	.251**	.517**	.75	31-60
Kans. (W)	17.2	.035	.010	.007	-.154	.337**	.478**	.66	51-60
Texas	12.1	.070	.012	.000	.312*	.159	.314	.53	31-60
Okla.	13.5	.115	.068	.000	.325+	.573**	-.350+	.58	31-60
Oats									
Mich.	32.0	.034	.017	.010	.272	.505**	-.068	.54	42-60
Wisc.	38.5	.029	.041	.015	-.182	.118	-.472	.35	42-60
Minn.	37.6	.045	.015	.000	-.372	.189+	-.589*	.45	42-60
Ohio	30.4	.028	.043	.014	.624+	.323	.784*	.56	42-60
Ind.	33.1	.042	.018	.000	.101	.201	.467	.48	42-60
Ill.	36.7	.091	.033	.001	.007	.349**	-.106	.54	42-60
Iowa	35.9	.025	.011	.000	.244	.763**	-.515	.59	42-60
Mo.	21.2	.125	.022	.000	.388+	.248+	-.106	.64	42-60

[a]Constant is coded by letting weather indices equal 1.0, N-P-K application rates equal zero and using '48 as base year.

[b]Notation (S) denotes spring wheat.

[c]Notation (W) denotes winter wheat.

**Tested statistically significant at the one percent level.

*Tested statistically significant at the five percent level.

+Tested statistically significant at the ten percent level.

Table 4.8 (Continued)

Crop State	Constant[a]	N+1.0	P+1.0	K+1.0	Acreage Index	Weather Index	Net Time Trend	R^2	Years
Oats									
N. Dak.	28.4	.045	.015	.000	.086	.420*	-.283	.55	42-60
S. Dak.	33.7	.084	.000	.000	-.654+	.729**	-1.682	.61	44-60
Nebr.	26.3	.057	.004	.000	-.289	.616**	-1.105+	.56	42-60
Kans.	21.9	.038	.014	.000	.220	.136	.391	.44	42-60
Texas	21.0	.049	.007	.006	.223*	.252*	.157	.49	42-60
Okla.	18.4	.119	.052	.000	.190**	.416**	-1.379**	.73	40-60
Soybeans									
Mich.	16.7	.017	.013	.017	-.056	.141	.392*	.73	42-60
Wisc.	12.7	.000	.018	.035	-.008	.207	-.378+	.54	42-60
Minn.	15.9	.000	.016	.018	-.144	.177	.288	.65	42-60
Ohio	19.3	.000	.019	.031	-.026	.208*	-.027	.66	41-60
Ind.	19.8	.002	.008	.012	-.022	.221	.375*	.82	41-60
Ill.	22.0	.005	.032	.034	-.153	.318*	-.272	.55	41-60
Iowa	21.3	.000	.016	.003	-.078	.402**	.303	.69	41-60
Mo.	17.9	.014	.010	.000	.134	.374**	.550+	.71	41-60
Ark.	15.1	.000	.035	.009	-.108	.196	.402	.36	43-60
Miss.	15.7	.000	.007	.005	.091	.310	.505	.56	43-60
Barley									
Minn.	24.1	.024	.013	.000	-.153	.414**	.907	.66	43-60
N. Dak.	21.1	.000	.045	.000	.332*	.213	-.426	.24	43-61
S. Dak.	19.0	.102	.015	.000	.323+	.415**	.125	.59	43-60
Nebr.	19.6	.064	.021	.000	-.064	.414**	-.134	.47	40-61
Flax									
Minn.	8.9	.031	.041	.010	-.052	.856**	.357	.45	44-61
N. Dak.	7.8	.066	.051	.002	-.010	.301	-.143	.26	44-61
S. Dak.	8.9	.107	.062	.000	-.196	.573*	-.450	.34	39-60
Cotton									
Texas	201.3	.011	.004	.008	.017	.270*	1.471**	.78	40-60
Okla.	176.7	.026	.009	.015	-.104	1.136**	1.716**	.70	39-60
Ark.	307.6	.046	.000	.031	-.394*	.503**	-.248	.74	41-60
Miss.	276.4	.069	.004	.002	.072	.658*	.546+	.55	39-60
Grain Sorghum									
Nebr.	20.9	.065	.006	.000	.137+	.460**	1.317**	.90	39-61
Kans.	18.1	.065	.006	.000	.232*	.363**	.145	.89	39-60
Texas	19.5	.053	.005	.005	.197+	.153*	1.222**	.88	39-60
Okla.	14.2	.053	.005	.005	.316*	.447**	.684+	.93	44-60

Table 4.8 (Continued)

Crop State	Constant[a]	Regression Coefficients N+1.0	P+1.0	K+1.0	Acreage Index	Weather Index	Net Time Trend	R^2	Years
Corn									
Mich.	38.8	.014	.009	.013	-.245	.749**	.253	.73	38-61
Wisc.	37.4	.029	.035	.051	-.365	.340**	-.075	.88	37-61
Minn.	43.3	.028	.012	.003	-.622**	.484**	-.013	.87	37-61
Ohio	37.0	.037	.085	.007	.167	.569**	.089	.72	39-61
Ind.	38.6	.016	.080	.015	-.346	.486**	-.101	.80	37-61
Ill.	47.7	.042	.014	.013	.260	.870**	.413**	.86	34-61
Iowa	51.1	.013	.007	.003	.150	1.185**	.199**	.87	26-61
Mo.	31.5	.070	.027	.004	-.124	1.203**	-.089	.85	37-61
N. Dak.	21.4	.051	.009	.000	-.833*	.895**	-.680*	.70	44-61
S. Dak.	24.4	.049	.022	.000	.907*	.695**	.419+	.75	37-61
Nebr.	26.8	.065	.000	.000	.185	.849**	.972**	.89	37-61
Kans.	23.4	.118	.000	.005	.501*	.661**	.303	.84	39-61
Texas	16.3	.055	.014	.001	.288+	.482**	-.145	.85	41-61
Okla.	18.1	.017	.012	.002	.123	.350**	-.037	.81	43-61
Ark.	14.7	.092	.007	.048	.317	.505**	-.091	.82	42-61
Miss.	12.1	.140	.004	.001	.133	.482**	.583**	.86	39-61
Tame Hay									
Mich.	1.28	.000	.053	.047	-.123	.707**	.044	.82	27-60
Wisc.	1.69	.064	.021	.046	.182	.760**	.254**	.84	27-60
Minn.	1.61	.000	.058	.007	.620**	.775**	.212**	.88	27-60
Ohio	1.27	.000	.044	.082	-.268	.793**	.128+	.85	27-60
Ind.	1.23	.007	.037	.080	-.044	.695**	.180**	.90	27-60
Ill.	1.46	.042	.088	.037	-.053	.592**	.338**	.94	27-60
Iowa	1.65	.013	.039	.000	.206	.580**	.401**	.83	27-60
Mo.	1.03	.040	.119	.021	-.250*	.595**	.304**	.78	27-60
N. Dak.	1.12	.000	.060	.000	.062	.703**	.022	.70	27-60
S. Dak.	1.18	.018	.039	.000	-.045	.516**	.259	.71	27-60
Nebr.	1.66	.000	.034	.000	-.270	.683**	.244**	.86	27-60
Kans.	1.65	.085	.607	.015	.025	1.008**	-.655	.07	27-60
Texas	.95	.048	.046	.000	-.159	.519**	-.042	.38	27-60
Okla.	1.10	.000	.141	.000	-.373*	.542**	-.445**	.61	27-60
Ark.	1.04	.026	.049	.024	-.108	.670**	-.075	.73	27-60
Miss.	1.06	.000	.065	.000	-.100	.616**	-.205**	.46	27-60
La.	1.07	.025	.033	.074	-.220	.558**	-.205**	.54	27-60

Table 4.9. Frequency distribution of R^2 values of state crop production functions

Crop	R^2-Values of State Crop Yield Regressions .00-.09	.10-.19	.20-.29	.30-.39	.40-.49	.50-.59	.60-.69	.70-.79	.80-.89	.90-.99	Number of Functions
Wheat					1	3	4	1	5		14
Oats				1	4	6	2	1			14
Soybeans				1		3	3	2	1		10
Barley			1		1	1	1				4
Flàx			1	1	1						3
Cotton							1	3			4
Grain Sorghum									2	2	4
Corn								3	13		16
Tame Hay	1			1	1	1	1	4	6	2	17
All Crops	1		2	4	8	14	12	14	27	4	86

and highest for production function estimates of corn and grain sorghums. The magnitude of these R^2 values seemed to depend on the statistical significance of weather indices. For example, only 6 out of 14 weather coefficients tested statsitically significant in the case of oats whereas in the case of corn all 16 weather coefficients tested statistically significant, at the one percent level. This finding merely confirms that weather is an important yield variable which needs to be measured accurately. However, reliable weather indices did not assure high R^2 values. For example, in the case of barley three out of four weather indices tested significant at the one percent level just as in the case of grain sorghums but all R^2 values of grain sorghum functions exceeded the .85 value while R^2 values of barley functions ranged from a high of .66 to a low of .24. Apparently identification of other crop yield variables was important.

Acreage index coefficients appeared to vary in size depending on crops and geographic location but variations by locations were less pronounced. Acreage index variables were defined as annual ratios of actual crop acres over trend line acres and were intended to measure effects of short run changes in acres on state yields of individual crops. Regression coefficients of acreage indices are listed in Table 4.10 and stratified by crops and states in Table 4.11. Only 23 out of 85 acreage coefficients tested statistically significant at one to ten percent levels. Approximately one half of the coefficients were negative and one half of the coefficients were positive. Eight out of ten acreage coefficients of the soybean production function were negative. Even though acreage coefficients of individual soybean production functions did not test significant at 10 percent levels they were quite consistently negative. Negative acreage coefficients implied reduction in state yields of soybeans whenever annual soybean acreages exceeded linear trend acreages. This result was in line with the apparent sensitivity of soybeans to geographic location. If soybean acreage is expanded it is important that varieties of appropriate maturity groups are grown. Soybeans are less responsive to fertilizer application than other major crops and therefore it is unlikely that yield decreases caused by growing soybeans in less favorable areas could be readily overcome by increased fertilizer use. Acreage

Table 4.10. Regression coefficients of ratios of actual over long run trend acreages by crops and states

State	Wheat	Oats	Soy-beans	Barley	Flax	Cotton	Grain Sorghum	Corn	Tame Hay
Ohio	.040	.624+	-.026					.167	-.268
Ind.	-.107	.101	-.022					-.346	-.044
Ill.	.032	.007	-.153					.260	-.053
Iowa	.013	.244	-.078					.150	.206
Mo.		.388+	.134					-.124	-.250*
Mich.	.192+	.272	-.056					-.245	-.123
Wisc.	-.173	-.182	-.008					-.365	.182
Minn.	.005	-.372	-.144	-.153	-.052			-.622**	.620**
N. Dak.	-.248	.086		.332*	-.196			-.833*	.062
S. Dak.	-.052	-.654		.323+	-.196			.907*	-.045
Nebr.	.073	-.289		-.064			.137+	.185	-.270
Kans.	-.154	.220					.232*	.501*	.025
Okla.	.335+	.190**				-.104	.316*	.123	-.373*
Texas	.312*	.223*				.017	.197+	.288+	-.159
Miss.			.091			.072		.133	-.100
Ark.			-.108			-.394*		.317	-.108

**Tested statistically significant at the one percent level.

*Tested statistically significant at the five percent level.

+Tested statistically significant at the ten percent level.

coefficients of tame hay and of production functions of crops grown in Michigan, Wisconsin, Minnesota and the Dakotas were negative in most cases. These results appear to imply that short run expansion of tame hay acreage and of most other crops in the northern states result in reduction of state yields of those crops. Conversely positive acreage coefficients of crops other than soybeans and tame hay of central and southern states appear to imply crop yield increases due to short run acreage expansions. In view of evident consistencies by crops and regions acreage variables were not excluded from the analysis even though most of them did not test statistically significant.

Table 4.11. Regression coefficients of net time trend by crops and states

	Wheat	Oats	Soy-beans	Barley	Flax	Cotton	Grain Sorghum	Corn	Tame Hay
Ohio	.253	.784*	-.027					.089	.128+
Indiana	.254	.467	.375					-.101	.180**
Ill.	.291**	-.106	-.272					.413	.338**
Iowa	.096	-.515	.303					.199**	.401**
Mo.		-.106	.550+					-.089	.304**
Mich.	.057	-.068	.392*					.253	.044
Wisc.	.400	-.472	-.378+					-.075	.254**
Minn.	-.121	-.589*	.288	.907	.357			-.013	.212**
N. Dak.	.467**	-.283		-.426	-.143			-.680*	.022
S. Dak.	.209	-1.682*		.125	-.450			.419+	.259
Nebr.	.517**	-1.105+		-.134			1.317**	.973**	.244**
Kansas	.478**	.391					.145	.303	-.655
Okla.	-.350+	-1.379**				1.716**	.684+	-.037	-.445**
Texas	.314	.157				1.471**	1.222**	-.145	-.042
Miss.						.546+		.583**	-.205**
Ark.						-.248		-.093	-.075

**Tested statistically significant at the one percent level.

*Tested statistically significant at the five percent level.

+Tested statistically significant at the ten percent level.

Time trend coefficients were of critical significance in this analysis. The time trend variable, denoted in formula 4.15 by T, was designed to pick up residual time trend effects after crop yields were deflated by annual variety indices and fertilizer yield response values. If time trend coefficients had been consistently negative it could have meant that the combined yield increase attributed to crop variety improvement and higher rates of fertilizer application was generally overestimated. Time trend coefficients were positive in most state crop production functions as shown in Table 4.11. Trend coefficients of oats were negative in 10 out of 14 state production functions and accounted for almost one-third of all negative coefficients. The computed yield increase of oats attributed to variety improvement and increased fertilizer application was not exceptionally large compared to that of other crops. Negative time trend coefficients of oats were not rejected as invalid because it appeared unlikely that they were caused by overestimation of oats variety improvement and fertilizer response. Other factors, arising from neglect of oats as a crop of declining importance, might have been responsible for the negative time trend. Negative signs of time trend coefficients of other state crop production functions did not appear related to crop or regional effects. It was concluded that the combined yield increase, attributed to variety improvement and increased fertilizer application, was generally not overestimated. Quantification of crop yield increase due to these technologies is considered most important in the current study and will be discussed in the next chapter.

CHAPTER V

IMPACT OF YIELD TECHNOLOGY ON U.S. CROP PRODUCTION

Analysis of the impact of technology on U.S. crop production builds on previous theoretical considerations and empirical estimates. In the last chapter state crop yields were estimated by production functions. In this chapter cause and effect relationships of crop yield change will be quantified by application of theoretical procedures outlined in Chapter II. For purpose of analysis each state is considered as a production unit composed of homogeneous farm firms. Different crops produced by the same state are considered as different enterprises. Annual crop yield changes due to variety improvement, change in fertilizer use and other crop yield variables will be quantified by crops, states, regions and in aggregate. In Chapter II it was shown that output optima of multi-product firms are identical to output optima of single-product firms provided there are no overall resource restrictions. Implicitly it was also assumed that output of one enterprise did not serve as input of another. The latter assumption can readily be satisfied as one crop e.g. corn, is usually not produced as input of another, e.g. soybeans. Prevalence of resource restrictions can not be ignored. In agriculture as in other industries land, labor, capital and management are subject to restrictions. As was demonstrated earlier resource restrictions reduce factor demand and product supply. Impact of these restrictions on crop yields will be expressed summarily by differences between expected and optimum state crop yields. Change in crop yields and cause of change will be discussed first. Effects of regional specialization will be quantified next. Then differences between expected and economic optimum yields will be estimated. Finally it will be indicated how this information can be used to project future crop supplies.

Change in Crop Yields and Cause of Change

To quantify impact of crop yield technology it is necessary to convert rates of technological change into comparable units. In the previous chapter estimated changes in crop yields due to variety improvement and fertilizer application were expressed in terms of relative changes and then used in combination with other variables for estimation of state crop production functions. In this chapter annual state crop yields are estimated according to these functions as in 5.1 and 5.2 where symbols denote, from left to right, state crop yield, constant term,

$$Y_j = bV\,(N_j+1.0)^n\,(P_j+1.0)^p\,(K_j+1.0)^k\,A_j^a\,W_j^w\,T_j^t\,e \qquad (5.1)$$

$$Y_j = bV\,(N_j+1.0)^n\,(P_j+1.0)^p\,(K_j+1.0)^k\,1.0^a\,1.0^w\,T_j^t \qquad (5.2)$$

variety index, application rates of nitrogen, phosphoric oxide and potash, acreage index, weather index, residual time trend and corresponding exponents. Formula 5.1 is the same as 4.15 except that prime notations of coefficients are dropped for simplicity and subscripts j are added to denote annual values of crop yield variables. <u>Expected</u> annual state crop yield Y_j is estimated according to 5.2 where annual acreage and weather indices are fixed at 1.00. Annual acreage indices measuring short run percentage changes of harvested acreage are fixed at unity as they might reflect acreage abandonment or acreage-price response rather than planned crop yield change. Also annual weather indices are set equal to unity because an index of 1.00 represents average weather and it is likely that farmers expect average rather than abnormal weather conditions at planning time.

To estimate the impact of specified technologies on state crop yield, equation 5.2 was simplified further. Three terms involving nutrients N, P, K and exponents n, p, k in equation 5.2 were replaced by a single term F_j as in equation 5.3 where F_j is defined by 5.4. Factor F_j represents

$$Y_j = bV_jF_jT_j^t \qquad (5.3)$$

$$F_j = (N+1.0)^n (P+1.0)^p (K+1.0)^k \qquad (5.4)$$

a ratio which measures relative nutrient response analogously to crop variety index V_j which measures relative response to variety improvement. Factor F_j changed from year to year with changes in fertilizer application and nutrient mix. Annual changes in state crop yield could then be approximated by application of a first term Taylor expansion as in 5.5 where

$$Y_{j+1} - Y_j \sim \left(\frac{\partial Y}{\partial V}\right)_j (V_{j+1}-V_j) + \left(\frac{\partial Y}{\partial F}\right)_j (F_{j+1}-F_j) + \left(\frac{\partial Y}{\partial T}\right)_j (T_{j+1}-T_j) \qquad (5.5)$$

yield change from crop year j to j+1 is attributed according to marginal productivities and changes of variety improvement, fertilization and other unidentified variables. In Chapter II conditions for validity of this approximation were specified, among others i was required that functions have continuous and finite partial derivatives up to any desired order. Since exponents of V_j and F_j equaled 1.0 only first order (partial) derivatives were non-zero. However, this did not seriously impair approximation as substitution of a slightly smaller exponent, say .999, makes 5.5 differentiable to any desired order if necessary. As annual weather variations were omitted from analysis year to year changes in state crop yields and individual yield variables were comparatively small. In order to change approximation 5.5 into an equality approximate values of individual terms were adjusted equiproportionately. Cumulative change in state crop yields was estimated by adding annual (adjusted) changes attributed to each variable.

As a rule approximation of annual changes of state crop yields by application of formula 5.5 was quite accurate. Ohio wheat yield data may serve as an empirical example. In Table 5.1 <u>expected</u> annual Ohio wheat yields Y_j, annual variety indices V_j and nutrient response values F_j are shown in columns 1 to 3. Annual yield changes attributed to other (unspecified) crop yield variables, variety improvement and change in fertilizer use are presented in columns 4 to 6 and cumulative yields are listed in columns 7 to 9. All data of Table 5.1 were derived from function 5.7 after simplification of Ohio wheat production function 5.6.

$$Y_j = 5.829\, V_j (N+1.0)_j^{.035} (P+1.0)_j^{.095} (K+1.0)_j^{.017}\, A_j^{.040} W_j^{0.104}\, T_j^{.253} \qquad (5.6)$$

$$Y_j = 5.829\, V_j\, F_j\, T_j^{.253} \qquad (5.7)$$

According to Table 5.1 (col. 1) expected wheat yield increased from 20.38 bushels in 1939 to 28.33 bushels in 1960. Over the same period variety indices advanced from .952 to 1.043 and fertilizer response values from 1.452 to 1.655 (Table 5.1, cols. 2 and 3). Annual crop variety indices increased year after year and consequently annual yield changes attributed

Table 5.1. Estimated contribution of variety improvement, fertilizer use and other crop yield variables to change in wheat yield, Ohio, 1939 to 1960

Year	Expected Yield (Y) Bu.	Variety Index (V_j)	Fertilizer Response (F_j)	Annual Yield Change			Cumulative Yields			Adjustm. Ratio
				Other Var. Bu.	Variety Bu.	Fertilizer Bu.	Other Var. Bu.	Variety Bu.	Fertilizer Bu.	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1939	20.38	.952	1.452	.000	.000	.000	14.04	14.04	20.38	0.00
1940	20.70	.960	1.453	.132	.163	.023	14.17	14.33	20.70	1.00
1941	21.10	.968	1.461	.131	.164	.108	14.30	14.63	21.10	1.00
1942	21.46	.975	1.465	.131	.166	.067	14.43	14.92	21.46	1.00
1943	22.02	.983	1.483	.129	.171	.253	14.56	15.23	22.02	1.00
1944	22.20	.990	1.475	.128	.169	-.112	14.69	15.52	22.20	1.01
1945	22.76	.992	1.501	.128	.043	.390	14.82	15.69	22.76	.99
1946	23.11	.995	1.511	.128	.064	.156	14.95	15.89	23.11	1.00
1947	23.75	.997	1.541	.128	.044	.456	15.07	16.06	23.75	1.00
1948	23.88	1.000	1.537	.127	.068	-.064	15.20	16.25	23.88	.99
1949	24.36	1.002	1.557	.126	.048	.302	15.33	16.43	24.36	1.00
1950	24.91	1.007	1.576	.126	.122	.307	15.45	16.68	24.91	1.00
1951	25.38	1.011	1.592	.127	.099	.245	15.58	16.90	25.38	1.00
1952	25.83	1.017	1.602	.126	.151	.164	15.71	17.18	25.83	1.00
1953	26.56	1.022	1.632	.127	.128	.484	15.83	17.43	26.56	1.01
1954	26.97	1.027	1.641	.127	.130	.150	15.96	17.69	26.97	1.00
1955	27.35	1.030	1.651	.127	.079	.174	16.09	17.90	27.35	1.00
1956	27.39	1.032	1.643	.122	.051	-.131	16.21	18.07	27.39	.97
1957	27.87	1.035	1.660	.124	.080	.279	16.33	18.28	27.87	1.00
1958	28.06	1.038	1.659	.123	.081	-.019	16.46	18.48	28.06	1.00
1959	28.14	1.041	1.653	.121	.080	-.117	16.58	18.68	28.14	.98
1960	28.33	1.043	1.655	.121	.054	.016	16.70	18.85	28.33	1.00

to variety improvement were positive for all years (Table 5.1, col. 5). Yield changes attributed to changes in fertilizer use were negative in five out of 22 years (Table 5.1, col. 6). For example yield change from 1943 to 1944 attributed to change in fertilizer use was -.112 bushels per acre. This negative change was a result of decline in estimated fertilizer response from 1.483 to 1.475 (Table 5.1, col. 3) and due to a reduction of fertilizer use from 38.0 to 35.6 pounds of N-P-K application per acre (Appendix Table C.13). Change in N-P-K application per acre did not necessarily lead to a corresponding change in fertilizer response. For example, from 1959 to 1960 estimated N-P-K application declined slightly from 84.6 to 84.1 pounds per acre (Appendix Table C.13) and yet estimated yield change was not negative but positive, although of the small magnitude of .016 bushels per acre. This positive change was caused by a one percent shift of the N-P-K ratio from potash to more productive phosphoric oxide and nitrogen which more than compensated for the small decline in application rate. Other (unspecified) crop yield variables raised wheat yields year after year as annual change in time trend variable T_j was unity and its regression coefficient was positive. Cumulative yields in Table 5.1, columns 7 to 9 were derived by adding annual yield changes to base yields 14.04 and 20.38. Base yield 14.04 represents estimated 1939 yield <u>without</u> fertilizer application and base yield 20.38 is estimated base yield <u>with</u> fertilizer application. Cumulative yields in columns 7, 8 and 9 estimate annual yields due to unspecified crop yield variables, annual yields due to unspecified crop yield variables plus variety improvement and annual yields due to unspecified crop yield variables plus variety improvement

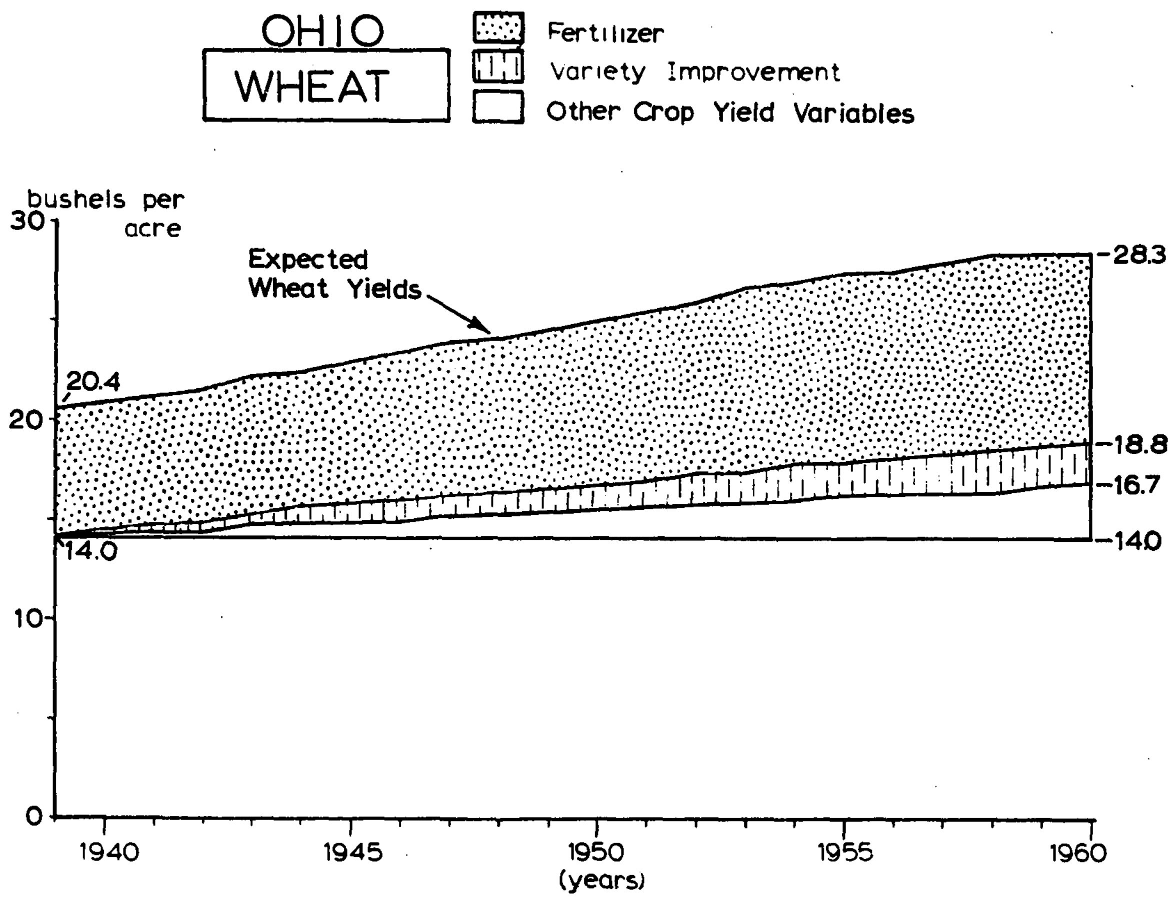


Figure 5.1. Expected wheat yields and cumulative change in yields due to fertilizer, variety improvement and other crop yield variables, Ohio, 1939 to 1960

plus fertilizer use, respectively. These cumulative yields are depicted in Figure 5.1 which illustrates how expected Ohio wheat yields increased over time and how much of the yield increase was attributed to increased fertilizer use, variety improvement and other crop yield variables. Values in columns 1 and 9 of Table 5.1 are identical but values in column 9 were estimated by adding annual changes attributed to different crop yield technologies to base yields. As mentioned earlier approximate values of annual yield change were adjusted equiproportionately. Annual adjustment ratios are shown in column 10 of Table 5.1. For estimated yield changes of .128, .169 and -.112 in 1944 (columns 4 to 6), for example, the adjustment ratio was 1.01, a one percent change of the approximate values. Considering that expected yields changed from an estimated 22.02 to 22.20 or by less than one fifth of a bushel the one percent adjustment of the change amounted to less than .002 bushels. Adjustment values in Table 5.1 were not exceptionally small. As a rule they were of similar magnitude for other crops and states. Only in cases of very small yield changes, say .01 bushels, were greater adjustments required.

Changes in crop yields over time were estimated annually by crops, states, regions and in aggregate. Procedures of estimation were analogous to those of Ohio wheat yields. In aggregating changes of crop yields into regional values an additional variable for estimating effects of regional specialization was added. Yield effects due to changes in location of production will be discussed later, for the time being they are included among other crop yield variables. Annual estimates of crop yield change differed between crops, regions and states. In Table 5.2 estimates of

Table 5.2 (Continued)

			Expected Crop Yields		Total Yield Change		
Crop	Time Period	Region State	First Year Bu.	Last Year Bu.	Relative %	Cumulative Bu.	Annual Increase
Oats	1942-60	Corn Belt	34.5	40.0	15.9	5.5	.31
		Ohio	32.0	50.3	57.2	18.3	1.02
		Ind.	31.8	45.3	42.5	13.5	.75
		Ill.	39.9	42.4	6.3	2.5	.14
		Iowa	37.2	36.3	-2.4	-.9	-.05
		Mo.	22.8	32.1	40.8	9.3	.52
		N. Plains	30.6	26.8	-12.4	- 3.8	-.21
		N. Dak.	28.5	30.2	6.0	1.7	.09
		S. Dak.	41.3	25.3	-38.7	-16.0	-.89
		Nebr.	29.4	23.8	-19.0	-5.6	-.31
		Kans.	21.0	28.2	34.3	7.2	.40
		S. Plains	19.8	23.9	20.7	4.1	.23
		Texas	20.2	24.6	21.8	4.4	.24
		Okla.	19.6	22.6	15.3	3.0	.17
Soybeans	1943-60	Lake States	15.0	21.3	42.0	6.3	.37
		Mich.	16.1	23.6	46.6	7.5	.44
		Wisc.	13.2	15.9	20.5	2.7	.16
		Minn.	15.0	21.3	42.0	6.3	.37
		Corn Belt	19.7	24.6	24.9	4.9	.29
		Ohio	19.6	24.1	23.0	4.5	.26
		Ind.	18.6	25.9	39.2	7.3	.43
		Ill.	21.1	25.4	20.4	4.3	.25
		Iowa	19.4	24.3	25.3	4.9	.29
		Mo.	15.4	22.0	42.9	6.6	.39
		Delta States[e]	12.6	19.7	56.3	7.1	.42
		Ark.	13.1	20.1	53.4	7.0	.41
		Miss.	11.7	18.7	59.8	7.0	.41
Barley	1943-60	Minn.	22.0	32.5	47.7	10.5	.62
		N. Plains[f]	20.4	23.6	15.7	3.2	.19
		N. Dak.	22.1	23.8	7.7	1.7	.10
		S. Dak.	18.6	22.2	19.4	3.6	.21
		Nebr.	19.9	22.9	15.1	3.0	.18

[e]Excluding Louisiana.

[f]Excluding Kansas.

Table 5.2 (Continued)

Crop	Time Period	Region State	Expected Crop Yields First Year Bu.	Last Year Bu.	Total Yield Change Relative Bu.	Cumulative Bu.	Average Bu.
Flax	1944-60	Minn.	8.8	9.7	10.2	.9	.06
		N. Plains[g]	8.1	7.2	-11.1	-.9	-.06
		N. Dak.	7.9	7.1	-10.1	-.8	-.05
		S. Dak.	8.7	7.8	-10.3	-.9	-.06
Cotton[h]	1939-60	S. Plains	137.1	316.5	130.9	179.4	8.54
		Texas	138.9	319.9	130.3	181.0	8.62
		Okla.	128.5	282.1	119.5	153.6	7.31
		Delta States[e]	314.6	447.0	42.1	132.6	6.31
		Ark.	345.0	437.6	26.8	92.6	4.41
		Miss.	289.0	455.6	57.6	166.6	7.93
Grain Sorghum	1939-60	N. Plains[i]	17.9	32.5	81.6	14.5	.70
		Nebr.	16.7	38.8	132.3	22.1	1.05
		Kans.	18.4	29.7	61.4	11.3	.54
		S. Plains	13.6	34.1	150.7	20.5	.98
		Texas	13.9	35.3	154.0	21.4	1.02
		Okla.	12.4	23.5	89.5	11.1	.53
Corn	1939-61	Lake States	35.3	55.9	58.4	20.6	.94
		Mich.	30.6	53.0	73.2	22.4	1.02
		Wisc.	35.3	61.8	75.1	26.5	1.20
		Minn.	37.0	54.1	46.2	17.1	.78
		Corn Belt	39.6	64.1	61.9	24.5	1.11
		Ohio	40.8	64.0	56.9	23.2	1.05
		Ind.	42.2	61.4	45.5	19.2	.87
		Ill.	40.5	71.4	76.3	30.9	1.40
		Iowa	43.4	63.9	47.2	20.5	.93
		Mo.	26.5	48.4	82.6	21.9	1.00

[g]Excluding Nebraska and Kansas.

[h]Crop Yields and crop yield changes measured in pounds.

[i]Excluding N. Dakota and S. Dakota.

Table 5.2 (Continued)

Crop	Time Period	Region State	Crop Yields First Year	Crop Yields Last Year	Total Yield Changes Relative	Total Yield Changes Cumulative	Total Yield Changes Average
			Bu.	Bu.	%	Bu.	Bu.
Corn	1939-61	N. Plains	19.1	40.9	114.1	21.8	.99
		N. Dak.	24.4	21.2	-13.1	-3.2	-.15
		S. Dak.	20.1	34.2	70.1	14.1	.64
		Nebr.	18.0	48.8	171.1	30.8	1.40
		Kans.	18.9	39.3	107.9	20.4	.93
		S. Plains	14.8	23.3	57.4	8.5	.39
		Texas	14.7	23.0	56.5	8.3	.38
		Okla.	15.2	25.1	65.1	9.9	.45
		Delta States[e]	14.0	29.9	113.6	15.9	.72
		Ark.	14.0	27.3	95.0	13.3	.60
		Miss.	14.0	30.6	118.6	16.6	.75
			tons	tons	%	tons	tons
Tame Hay	1939-60	Lake States	1.513	1.876	24.0	.363	.0173
		Mich.	1.318	1.500	13.8	.182	.0087
		Wisc.	1.615	2.027	25.5	.412	.0196
		Minn.	1.553	1.911	23.1	.358	.0170
		Corn Belt	1.315	1.662	26.4	.347	.0165
		Ohio	1.303	1.661	27.5	.358	.0170
		Ind.	1.281	1.598	24.7	.317	.0151
		Ill.	1.362	1.752	28.6	.390	.0186
		Iowa	1.517	1.875	23.6	.358	.0170
		Mo.	1.052	1.336	27.0	.284	.0135
		N. Plains[j]	1.262	1.406	11.4	.144	.0069
		N. Dak.	1.119	1.177	5.2	.058	.0028
		S. Dak.	1.121	1.263	12.7	.142	.0068
		Nebr.	1.590	1.786	12.3	.196	.0093
		S. Plains	1.058	1.100	4.0	.042	.0020
		Texas	.962	1.012	5.2	.050	.0024
		Okla.	1.208	1.238	2.5	.030	.0014
		Delta States[e]	1.108	1.198	8.1	.090	.0043
		Ark.	1.056	1.120	6.1	.064	.0030
		Miss.	1.153	1.196	3.7	.043	.0020
		La.	1.176	1.325	12.7	.149	.0071

[j]Excluding Kansas.

expected crop yields are tabulated for the first and last year of selected time periods, also estimates of total and average annual changes are presented. Corresponding annual estimates and breakdown of annual cumulative crop yield change by cause of change are shown in Figures 5.2 to 5.53. Table 5.2 and Figures 5.2 to 5.53 will be discussed summarily by crops.

Wheat According to Table 5.2 wheat yields of the Lake States increased by 67.7 percent from 1939 to 1960, representing the greatest increase in wheat yields among major producing regions. Over this time period yields in the Lake States advanced from 16.1 to 27.0 bushels at an annual rate of .52 bushels per acre. In contrast percentage increase of wheat yields in the Southern Plains was estimated at 39.2 percent at an annual rate of .22 bushels per acre over the same time period. As evident from Figure 5.2 more extensive fertilizer use, strong improvement in varieties and positive yield effects of other but unspecified variables were responsible for greater rise in wheat yields of Lake States. In Michigan wheat yields rose due to an increase in N-P-K application (from 19.8 pounds in 1939 to 109.8 pounds in 1961) and introduction of Genessee, a variety of much higher yielding ability (Appendix Table A.56 and C.7). In Minnesota application rates increased from less than one pound in 1939 to over 30 pounds in 1960 while adoption of spring wheat varieties Lee and Selkirk raised yields markedly during the last decade (Appendix Tables A.57 and C.8). Wheat yield changes in Wisconsin followed an intermediate pattern but were of less import because Wisconsin wheat acreage was small relative to Michigan and Minnesota acreages. Annual expected yields are shown in Figure 5.7 by states, they clearly illustrate progress of Michigan

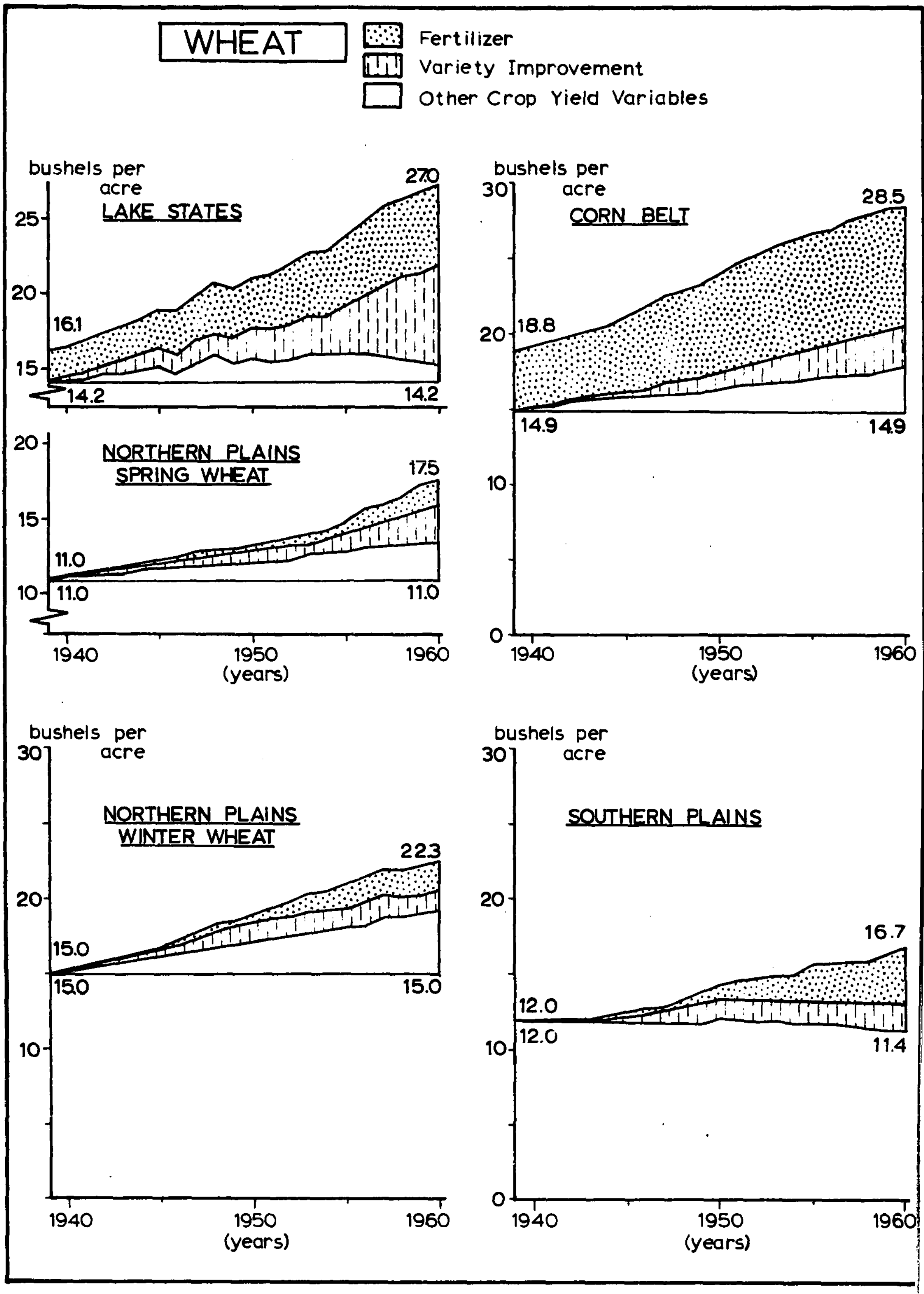
Figure 5.2. Wheat yield change due to crop yield technology, Lake States, 1939 to 1960

Figure 5.3. Wheat yield change due to crop yield technology, Corn Belt (excl. Missouri), 1939 to 1960

Figure 5.4. Spring wheat yield change due to crop yield technology, Northern Plains (excl. Kansas), 1939 to 1960

Figure 5.5. W. wheat yield change due to crop yield technology, Northern Plains (excl. N. Dakota), 1939 to 1960

Figure 5.6. Wheat yield change due to crop yield technology, Southern Plains, 1939 to 1960



WHEAT
Fertilizer
Variety Improvement
Other Crop Yield Variables
bushels per acre
LAKE STATES
27.0
16.1
14.2
14.2
NORTHERN PLAINS SPRING WHEAT
17.5
11.0
11.0
11.0
CORN BELT
28.5
18.8
14.9
14.9
NORTHERN PLAINS WINTER WHEAT
22.3
15.0
15.0
15.0
SOUTHERN PLAINS
16.7
12.0
12.0
11.4
1940
1950
1960
(years)

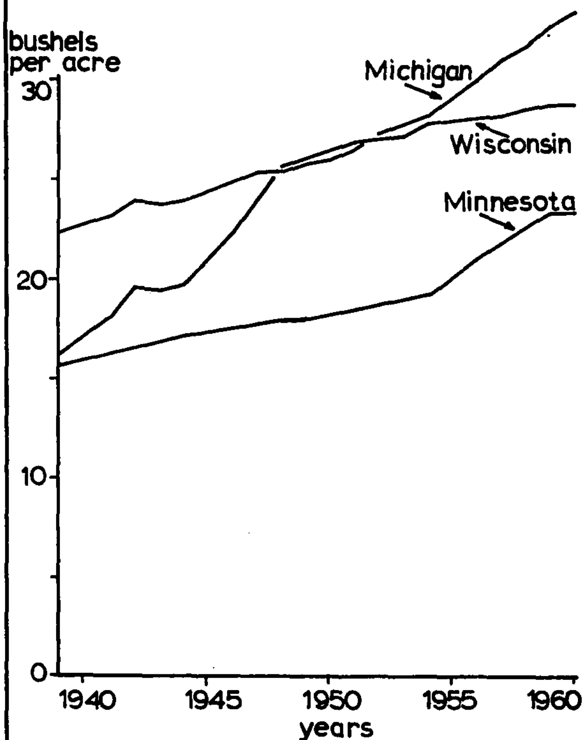


Figure 5.6. Expected wheat yields, Lake States, 1939-60

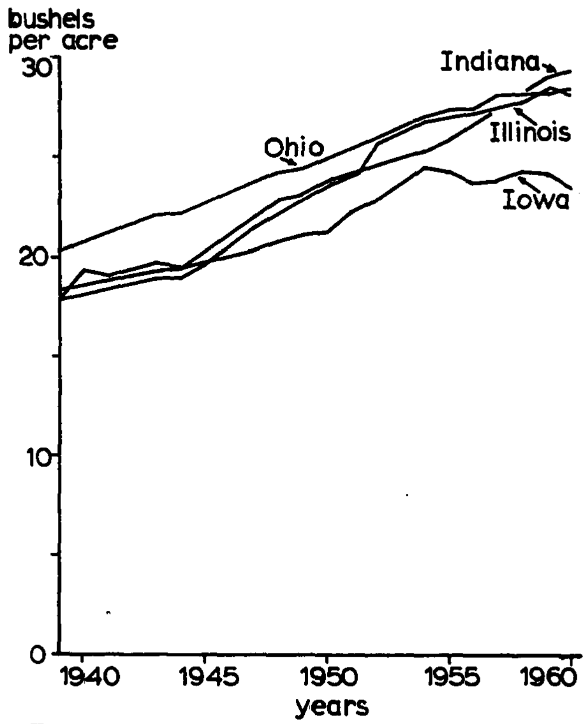


Figure 5.8. Expected wheat yields, Corn Belt States, 1939-60

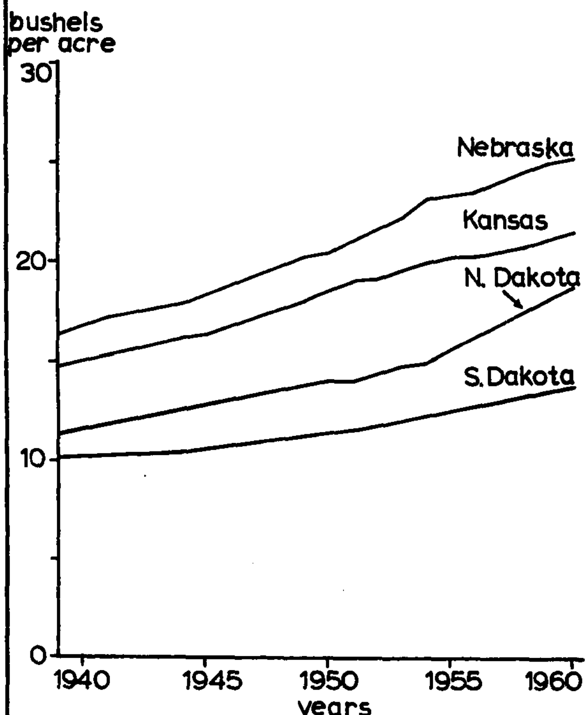


Figure 5.9. Expected wheat yields, N. Plains States, 1939-60

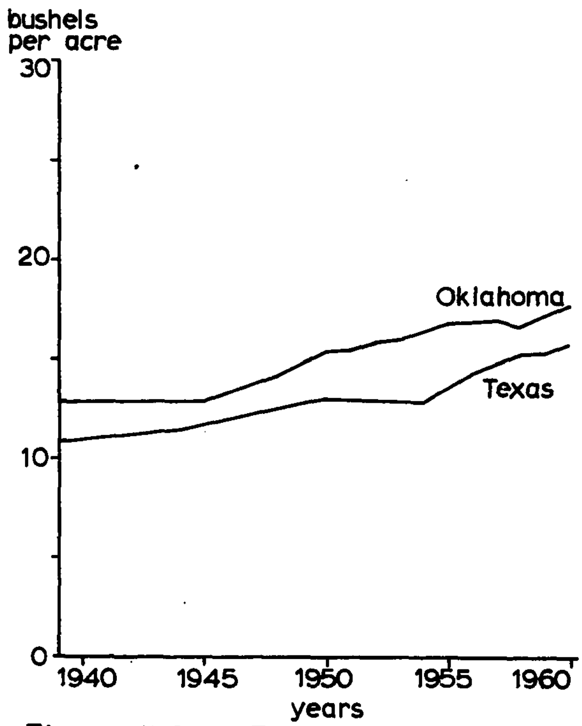


Figure 5.10. Expected wheat yields S. Plains States, 1939-60

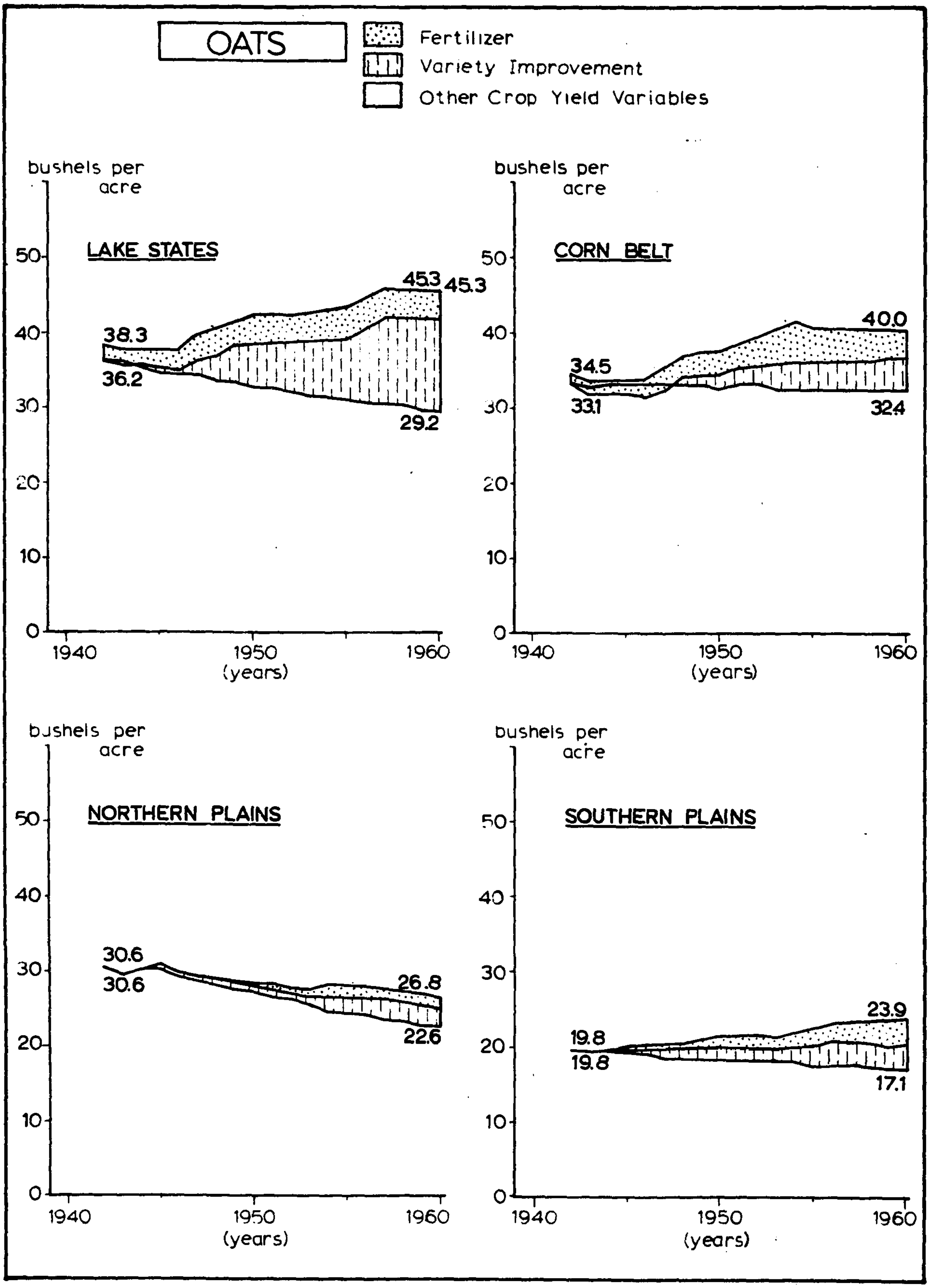
and Minnesota wheat yields in recent years. In the Corn Belt region relative yield increase was 51.6 percent and annual increase was .46 bushels, almost as high as in the Lake States. Most of this increase came from higher rates of fertilizer application which exceeded corn rates by a considerable margin until more recent years (Figure 5.3). In Iowa and Illinois expected yields declined because less fertilizer was applied in later years (Figure 5.8). Annual yield increase in the spring and winter wheat regions of the Northern Plains was .31 and .35 bushels respectively and lower than in Lake States and Corn Belt regions. According to Table 5.2 relative yield increase was greater for the spring wheat than winter wheat region of the Northern Plains, the opposite was true for yield increase in bushels. Percentage increase was greater for spring wheat because spring wheat yields were lower than winter wheat yields throughout the period as shown in Figure 5.9 where yield lines of the Dakotas represent spring wheat yields and yield lines of Kansas and Nebraska depict winter wheat yields. A considerable portion of the yield increase in the Northern Plains area was due to yield effects of other crop yield variables (Figures 5.4 and 5.5). As summer fallow acreage of the Northern Plains has been greatly expanded during the last two decades it is likely that much of this "unexplained" yield increase was due to shift from wheat - wheat to fallow - wheat rotation. In North Dakota, for example, spring wheat acreage (excluding Durum Wheat) planted after summer fallow increased from 37.4 percent in 1949 to 61.9 percent in 1960 (47). In the Southern Plains States Texas and Oklahoma, winter wheat yields were lower than in other winter wheat areas; after deduction of fertilizer and variety improvement

Figure 5.11. Oat yield change due to crop yield technology, Lake States, 1942 to 1960

Figure 5.12. Oat yield change due to crop yield technology, Corn Belt, 1942 to 1960

Figure 5.13. Oat yield change due to crop yield technology, Northern Plains, 1942 to 1960

Figure 5.14. Oat yield change due to crop yield technology, Southern Plains, 1942 to 1960


OATS
Fertilizer
Variety Improvement
Other Crop Yield Variables
bushels per acre
LAKE STATES
38.3
36.2
45.3
45.3
29.2
CORN BELT
34.5
33.1
40.0
32.4
NORTHERN PLAINS
30.6
30.6
26.8
22.6
SOUTHERN PLAINS
19.8
19.8
23.9
17.1
1940
1950
1960
(years)

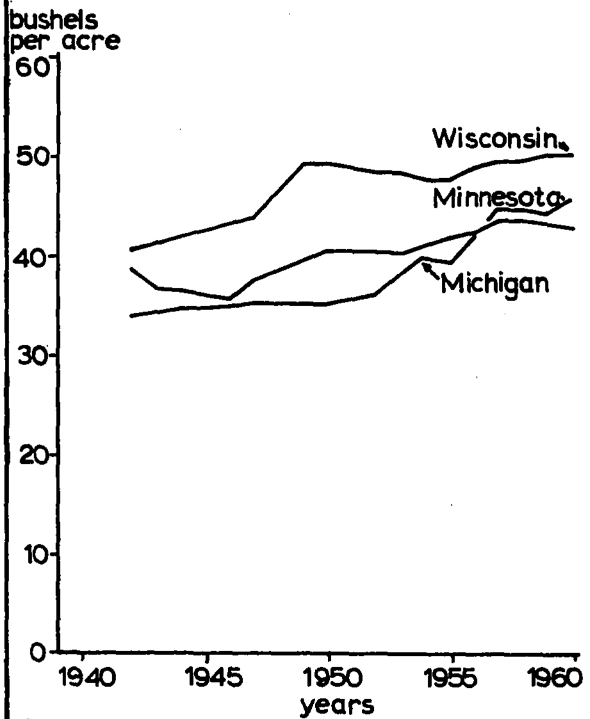


Figure 5.15. Expected oats yields, Lake States, 1942-60

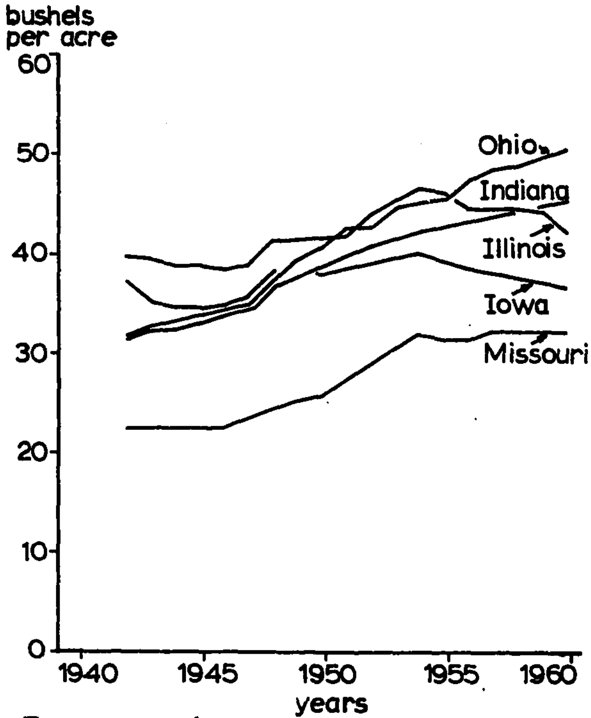


Figure 5.16. Expected oats yields, Corn Belt States, 1942-60

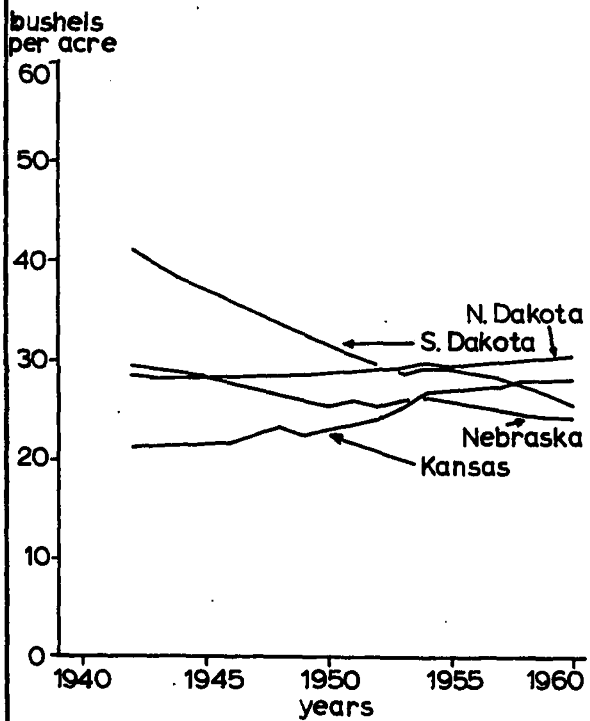


Figure 5.17. Expected oats yields, N. Plains States, 1942-60

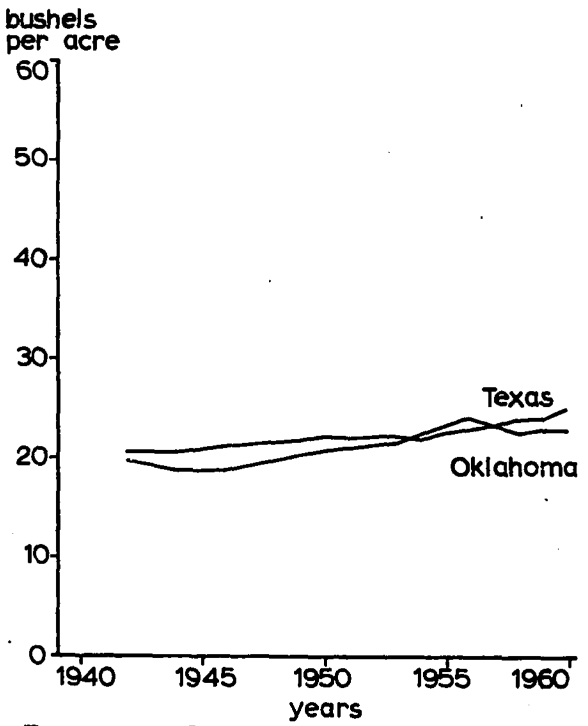


Figure 5.18. Expected oats yields, S. Plains States, 1942-60

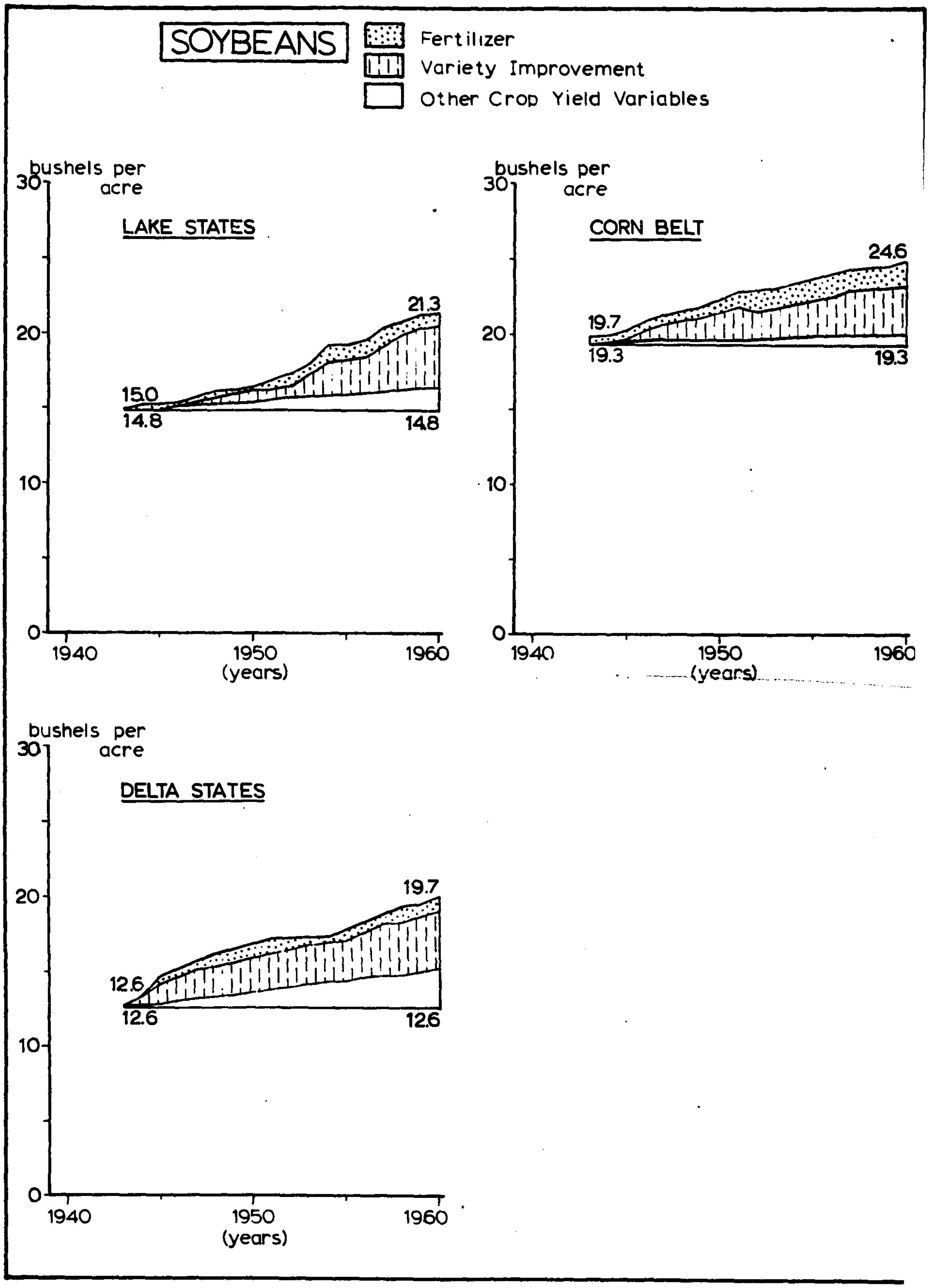
effects, yields declined from 12.0 bushels in 1939 to 11.4 bushels in 1960 (Figure 5.6). What factors were responsible for this decline remained unknown. Wheat yields in both States rose at similar rates (Figure 5.10) but yield reduction due to other crop yield variables was greater in Oklahoma than in Texas.

<u>Oats</u> In most regions yield increase of oats was lower than wheat yield increase. Annual yield increase in the Lake States was .39 bushels and highest among all regions (Table 5.2). Corresponding yield increases in the Corn Belt, Northern Plains and Southern Plains were .31, -.21 and .23 bushels respectively. Effects of fertilization, variety improvement and other crop yield variables are shown in Figures 5.11 to 5.14. After accounting for yield increase due to fertilizer application and variety improvement oats (net) yields declined in all regions as time trend variables measuring net effects of other crop yield variables were negative in oats production functions of most states. In the Northern Plains expected oat yields declined in spite of higher rates of fertilizer application and variety improvements. It is unlikely however that this was attributable to overestimation of fertilizer and variety improvement effects as both were quite small. Negative trend effects were strongest in South Dakota and followed by Nebraska as illustrated in Figure 5.17. Positive oat yield trends in North Dakota and Kansas did not compensate for declining yields in the other two states. State oats yields of other regions moved upward as shown in Figures 5.15, 5.16 and 5.18 but yield increase was not very pronounced. Possibly rotational changes or moving oats on poorer crop land had adverse effects on oats yields.

Figure 5.19. Soybean yield change due to crop yield technology, Lake States, 1943 to 1960

Figure 5.20. Soybean yield change due to crop yield technology, Corn Belt, 1943 to 1960

Figure 5.21. Soybean yield change due to crop yield technology, Delta States (excl. Louisiana), 1943 to 1960



SOYBEANS
Fertilizer
Variety Improvement
Other Crop Yield Variables
bushels per acre
LAKE STATES
21.3
15.0
14.8
14.8
CORN BELT
24.6
19.7
19.3
19.3
DELTA STATES
19.7
12.6
12.6
12.6
0
10
20
30
1940
1950
1960
(years)

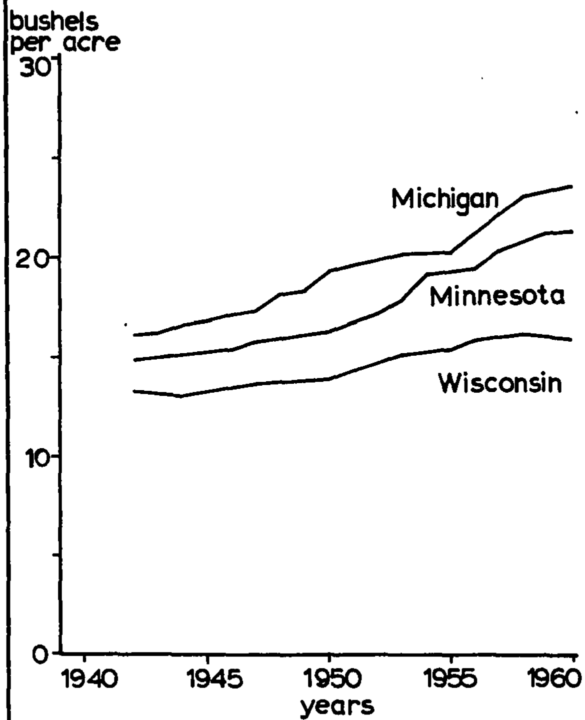


Figure 5.22. Exp. soybean yields, Lake States, 1943-60

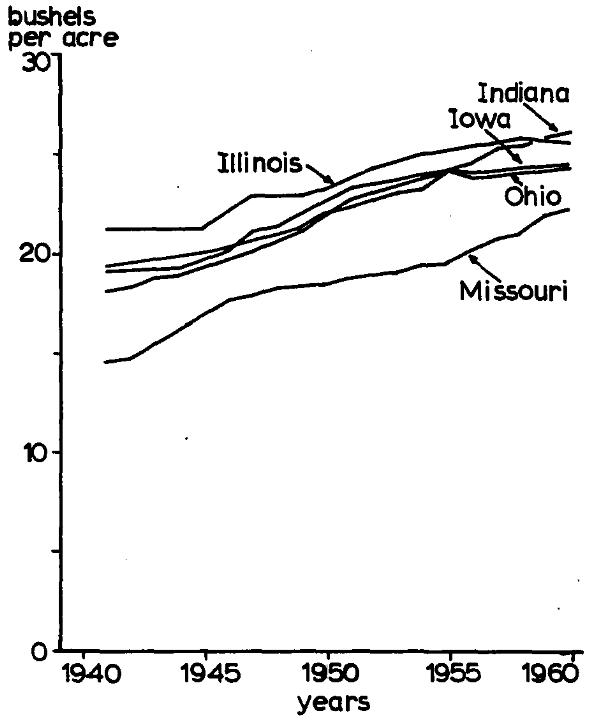


Figure 5.23. Exp. soybean yields, Corn Belt States, 1943-60

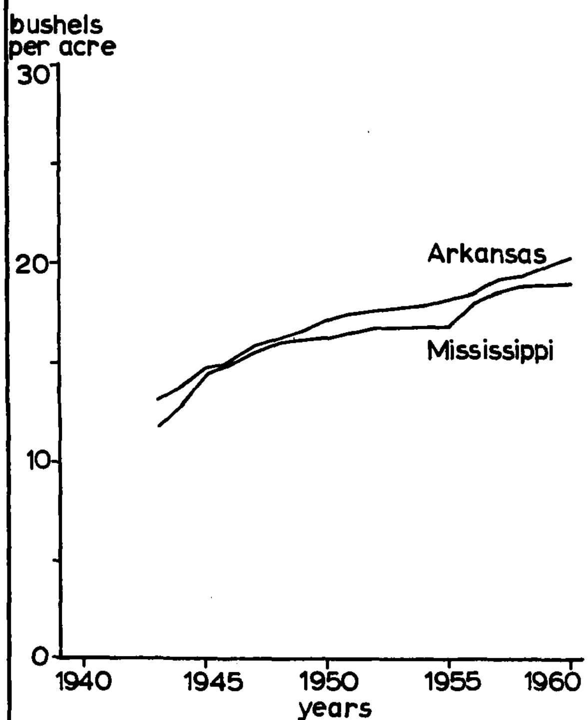


Figure 5.24. Exp. soybean yields, Delta States, 1943-60

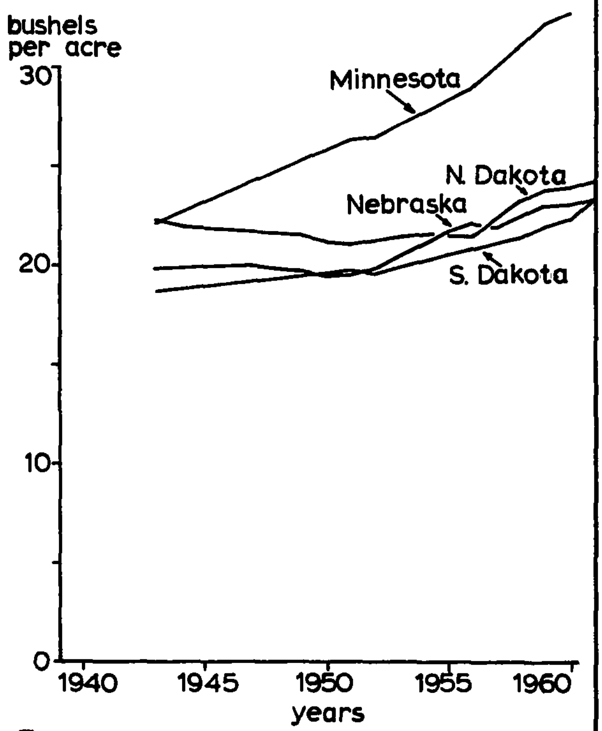


Figure 5.25. Exp. barley yields, Minn. and N. Plains, 1943-60

Soybeans   Estimated soybean yields advanced in all regions. The greatest yield increase was estimated for the Delta States at 56.3 percent, it was followed by a 42.0 percent increase of the Lake States and a 24.9 percent increase of the Corn Belt (Table 5.2). Yield change in terms of bushels was in corresponding order with a 7.1 bushel change in the Delta States, a 6.3 and 4.9 bushel change in the Lake States and Corn Belt respectively. As shown in Figures 5.19, 5.20 and 5.21 variety improvement was the primary cause of higher soybean yields in all regions. Additional fertilizer use raised regional yields by less than two bushels per acre. Yield effects of other unspecified crop yield variables were positive in all regions and greatest among Delta States. The fact that other crop yield variables increased rather than decreased soybean yields in all regions will be of particular significance for the discussion of aggregate soybean yields later. Advance in soybean yields was quite uniform among states as demonstrated by Figures 5.22 to 5.24. It is noticeable, however, that soybean yields increased in Delta States strongly during the forties and in the Lake States at a more rapid pace during the fifties. This differential rate of advance was caused by adoption of early maturing varieties in northern regions during later years which was discussed in Chapter IV under Variety Improvement.

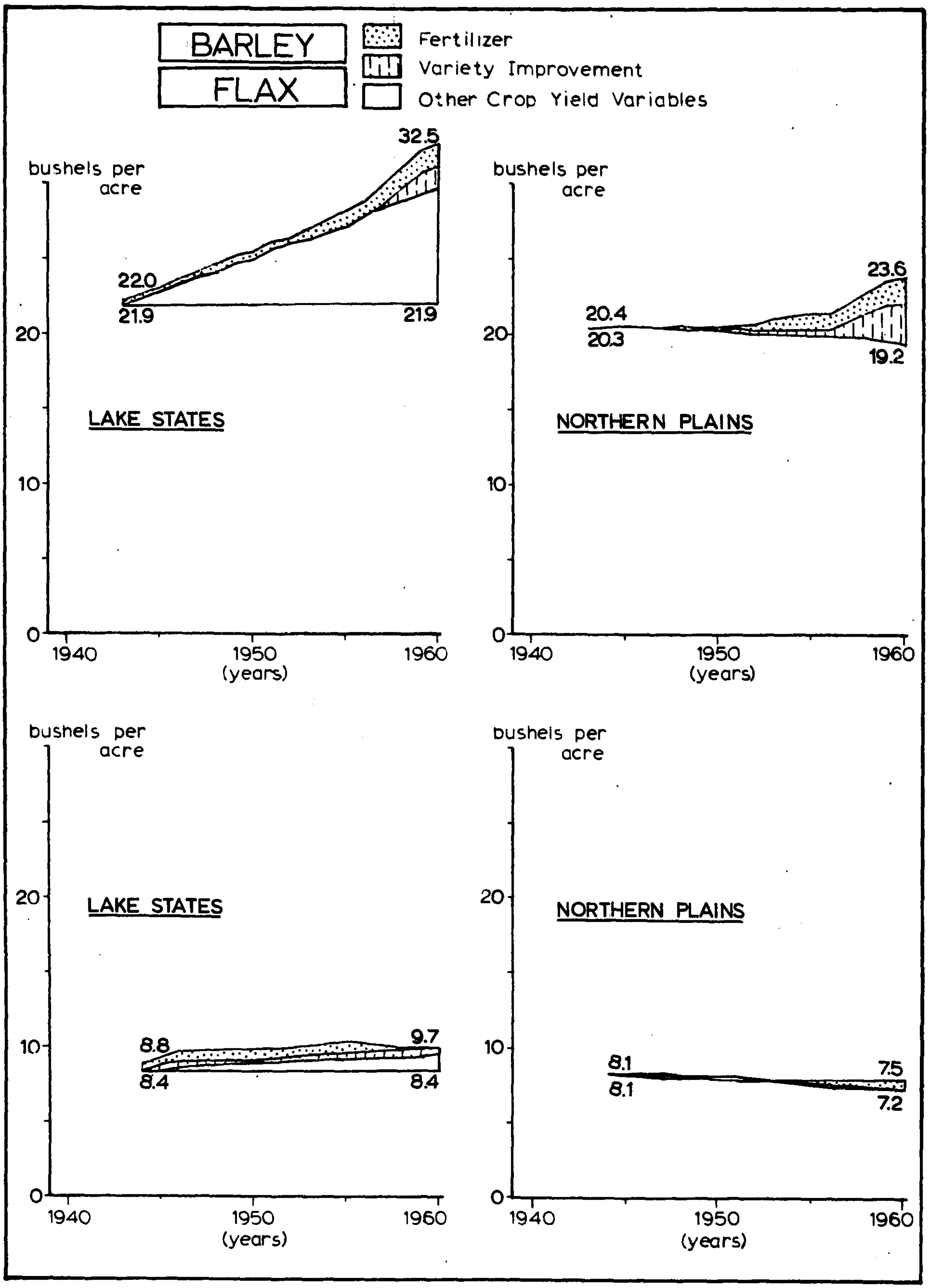
Barley, flax, cotton and grain sorghum   Barley yields increased most in Minnesota, from an estimated 22.0 bushels in 1943 to 32.5 bushels in 1960 (Table 5.2). In Northern Plains states barley yields advanced quite uniformly but at a much lower rate of .19 bushels compared to .62 bushels per acre in Minnesota. Annual yield curves in Figure 5.25 clearly

Figure 5.26. Barley yield change due to crop yield technology, Lake State Minnesota, 1943 to 1960

Figure 5.27. Barley yield change due to crop yield technology, Northern Plains (excl. Kansas), 1943 to 1960

Figure 5.28. Flax yield change due to crop yield technology, Lake State Minnesota, 1944 to 1960

Figure 5.29. Flax yield change due to crop yield technology, Northern Plains States N. Dakota and S. Dakota, 1944 to 1960


BARLEY
FLAX
Fertilizer
Variety Improvement
Other Crop Yield Variables
bushels per acre
32.5
22.0
21.9
21.9
LAKE STATES
bushels per acre
23.6
20.4
20.3
19.2
NORTHERN PLAINS
bushels per acre
LAKE STATES
8.8
9.7
8.4
8.4
bushels per acre
NORTHERN PLAINS
8.1
7.5
8.1
7.2
0
10
20
1940
1950
1960
(years)

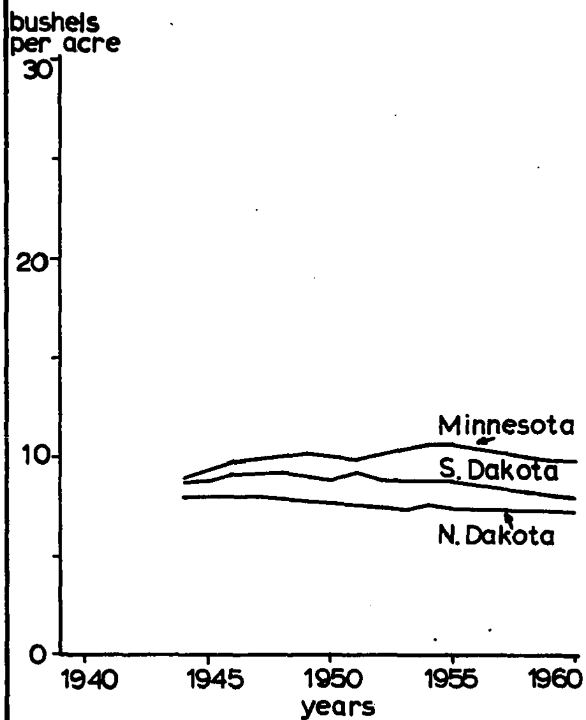


Figure 5.30. Exp. flax yields, Minn., N. and S. Dakota, 1944-60

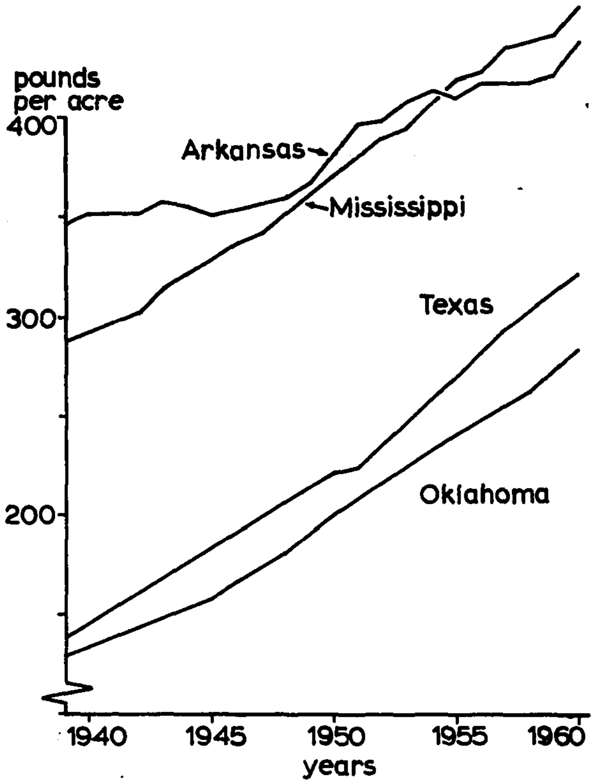


Figure 5.31. Exp. cotton yields, S. Plains and Delta States, 1939-61

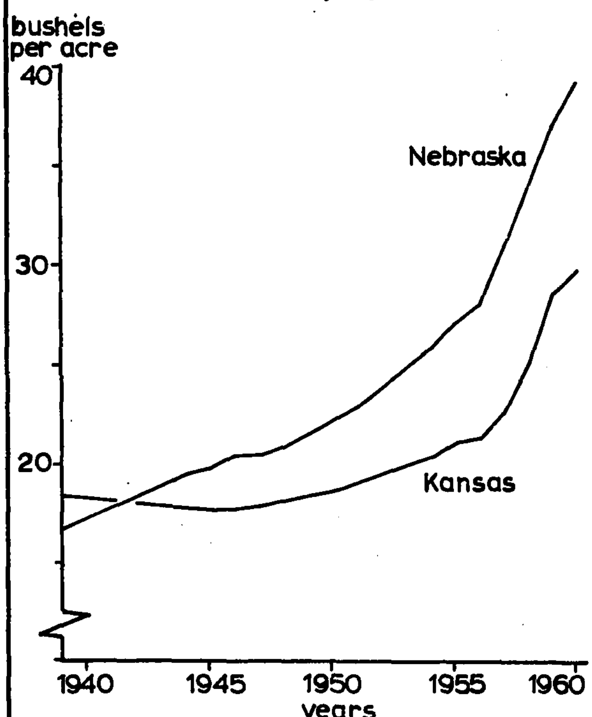


Figure 5.32. Exp. grain sorghum yields, Nebr. and Kan., 1939-60

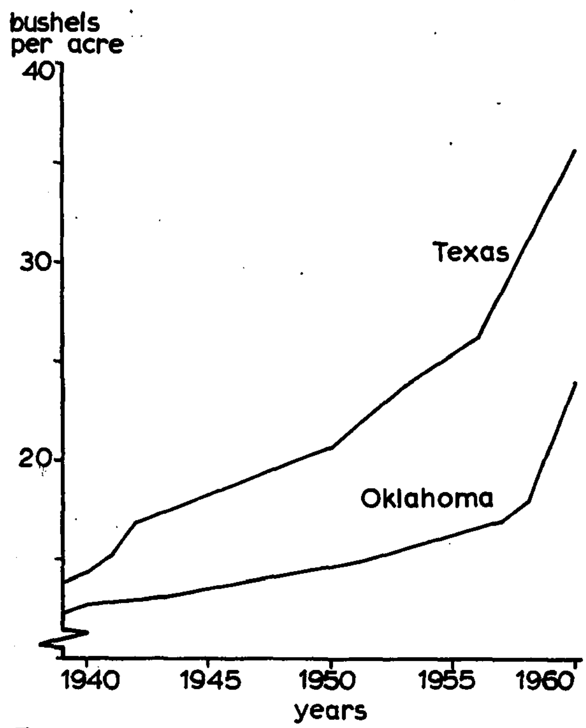


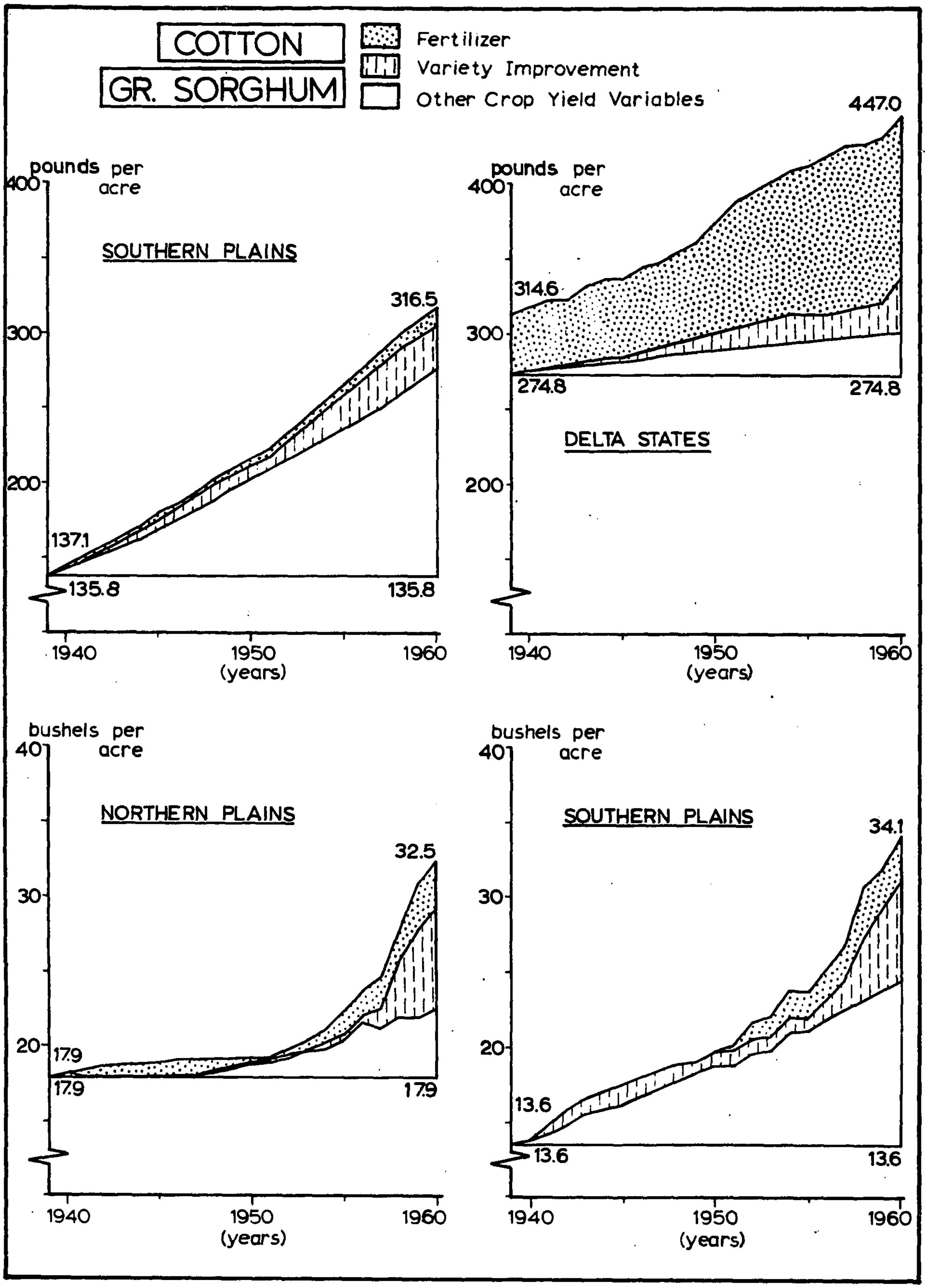
Figure 5.33. Exp. grain sorghum yields, S. Plains States, 1939-60

Figure 5.34. Cotton yield change due to crop yield technology, Southern Plains, 1939 to 1960

Figure 5.35. Cotton yield change due to crop yield technology, Delta States (excl. Louisiana), 1939 to 1960

Figure 5.36. Grain sorghum yield change due to crop yield technology, Northern Plains States Nebraska and Kansas, 1939 to 1960

Figure 5.37. Grain sorghum yield change due to crop yield technology, Southern Plains, 1939 to 1960


COTTON
GR. SORGHUM
Fertilizer
Variety Improvement
Other Crop Yield Variables
pounds per acre
SOUTHERN PLAINS
316.5
137.1
135.8
135.8
1940
1950
(years)
1960
pounds per acre
447.0
314.6
274.8
274.8
DELTA STATES
1940
1950
(years)
1960
bushels per acre
NORTHERN PLAINS
32.5
17.9
17.9
17.9
1940
1950
(years)
1960
bushels per acre
SOUTHERN PLAINS
34.1
13.6
13.6
13.6
1940
1950
(years)
1960

illustrate this difference in yield changes, but the cause of it was entirely attributed to other unspecified crop yield variables as a comparison between Figures 5.26 and 5.27 reveals. Rates of yield increase accelerated in more recent years in both regions due to rapid adoption of Traill, a higher yielding barley variety (see Chapter IV, Variety Improvement). Flax yields advanced from 8.8 to 9.8 bushels but declined by .8 bushels in North Dakota and by .9 bushels in South Dakota over a 16 year period (Table 5.2). It is noteworthy that very little yield increase was attributed to fertilization or variety improvement (Figures 5.28, 5.29). It may be recalled that the North Dakota flax variety index declined rather than increased and therefore exerted a yield decreasing effect on regional flax yields in the Northern Plains. Estimated flax yields of South Dakota declined even though the variety index increased slightly (Figure 5.30).

- In contrast cotton yields advanced at a remarkable pace, especially in Texas and Oklahoma where estimated yields more than doubled over a period of 21 years (Table 5.2). While Texas cotton yields exceeded the 300 lbs. level, Arkansas and Mississippi yields surpassed the 400 lbs. level although yield increase in the Delta States was not quite as pronounced (Figure 5.31). Much of the cotton yield increase in Southern Plains states could not be explained by higher rates of fertilizer application or variety improvement (Figure 5.34), most of it was apparently a result of other crop yield variables. Presumably expansion of irrigated acreage contributed greatly to higher cotton yields in Texas. In the Texas High Plains, a highly specialized cotton area which produced in the 1950's about eight percent of all U.S. cotton, yields of cotton nearly tripled from 1944 to 1954 in response to irrigation (48, p. 131). Most of the yield increase in the Delta States was attributed to increased fertilizer use. Variety improvement and other crop yield variables contributed nearly the same to yield change (Figure 5.35). - Relative gains of grain sorghum yields were even greater. In Kansas yields of grain sorghum increased by about 60 percent, in Oklahoma by 90 percent, in Nebraska and Texas by over 130 percent from 1939 to 1960 (Table 5.2 and Figures 5.32 and 5.33). What were the causes of this drastic yield change? In Southern Plains states the greatest part of the increase was again due to unspecified crop yield variables, but about half of the yield increase was explained by variety improvement and heavier rates of fertilizer application. In Northern Plains States Nebraska and Kansas most of the rise was attributed to variety improvement and fertilizer and only one third of the increase to other yield variables. Again expansion of irrigated acreage may have raised yields of grain sorghum in these states but a large portion of the yield increase occurred at the end of the last decade and was due to adoption of sorghum hybrids (Figures 5.36 and 5.37). How quickly farmers adopted sorghum hybrids was described earlier (Chapter IV, Variety Improvement).

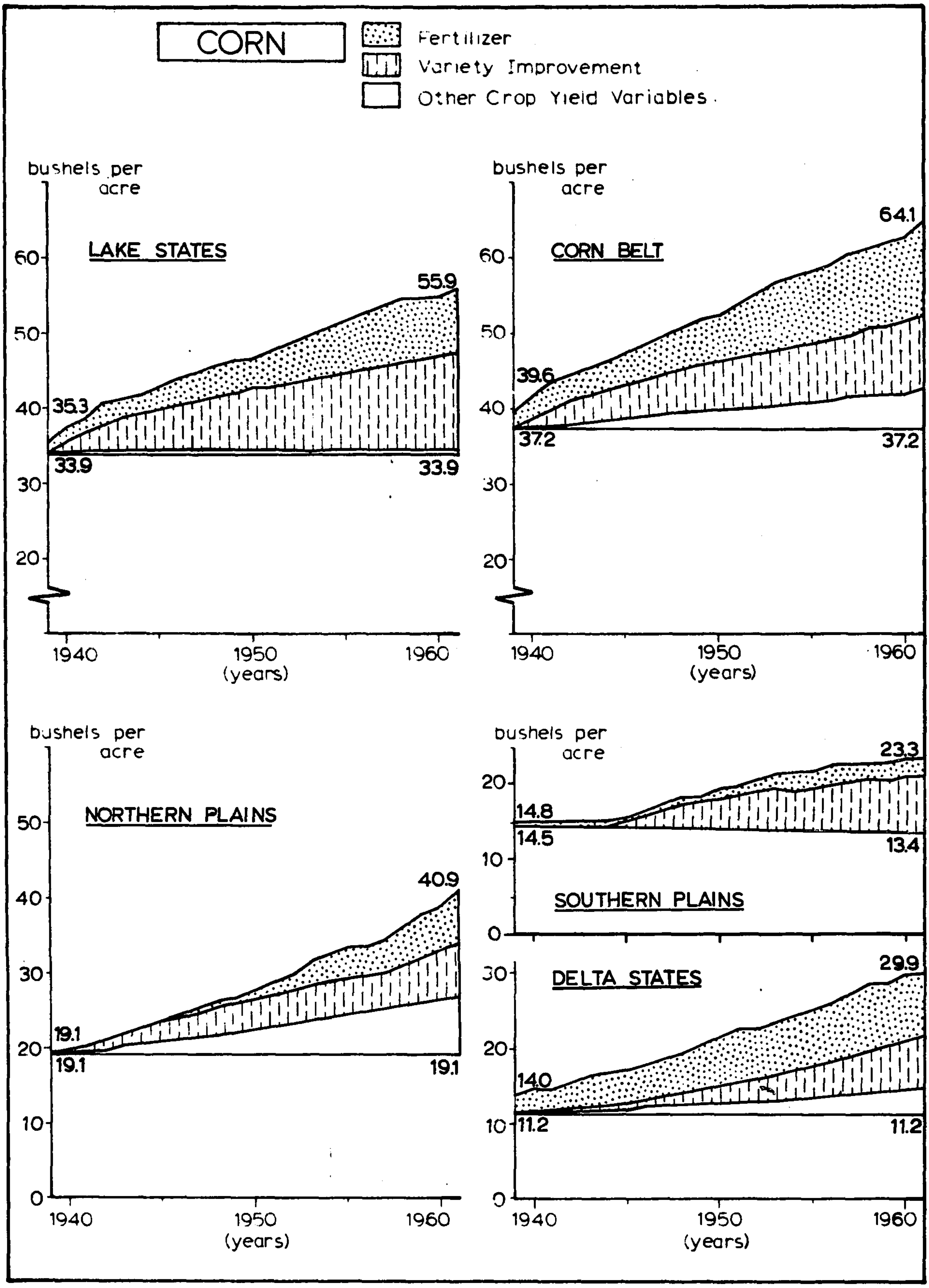
<u>Corn</u> Yields advanced strongly in all regions. Percentage-wise the greatest increase occurred in the Delta States and Northern Plains, both regions attained a 114 percent yield increase from 1939 to 1961. However, in terms of bushels yield increase was greatest in the Corn Belt, traditionally the most productive region, where expected yields increased from 39.6 in 1939 to 64.1 bushels in 1961 at a rate of 1.11 bushels per year (Table 5.2). In all regions fertilization and continued improvement

Figure 5.38. Corn yield change due to crop yield technology, Lake States, 1939 to 1961

Figure 5.39. Corn yield change due to crop yield technology, Corn Belt, 1939 to 1961

Figure 5.40. Corn yield change due to crop yield technology, Northern Plains, 1939 to 1961

Figure 5.41. Corn yield change due to crop yield technology, Southern Plains and Delta States (excl. La.), 1939 to 1961


CORN
Fertilizer
Variety Improvement
Other Crop Yield Variables
bushels per acre
LAKE STATES
55.9
35.3
33.9
33.9
CORN BELT
64.1
39.6
37.2
37.2
1940
1950
1960
(years)
NORTHERN PLAINS
40.9
19.1
19.1
19.1
SOUTHERN PLAINS
23.3
14.8
14.5
13.4
DELTA STATES
29.9
14.0
11.2
11.2

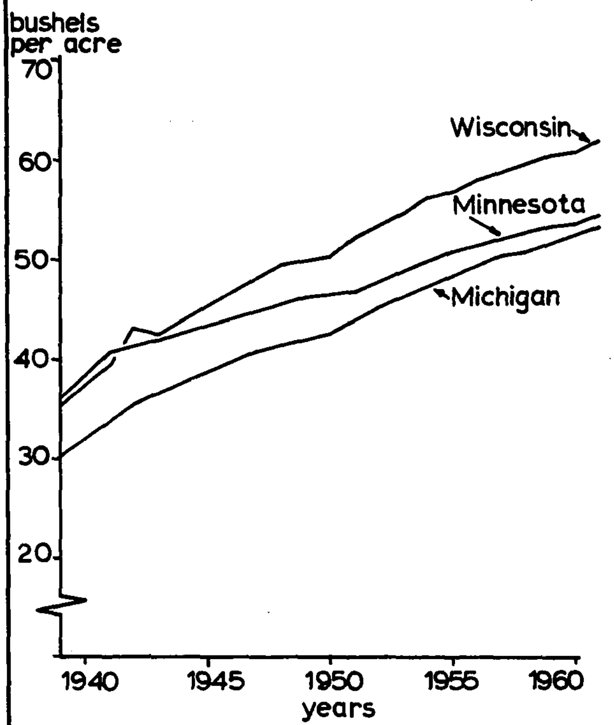


Figure 5.42. Exp. corn yields, Lake States, 1939-61

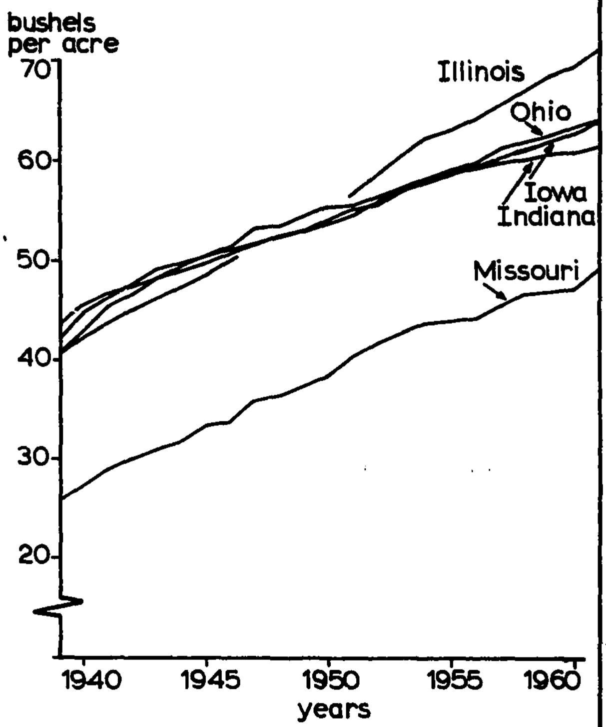


Figure 5.43. Exp. corn yields, Corn Belt, 1939-61

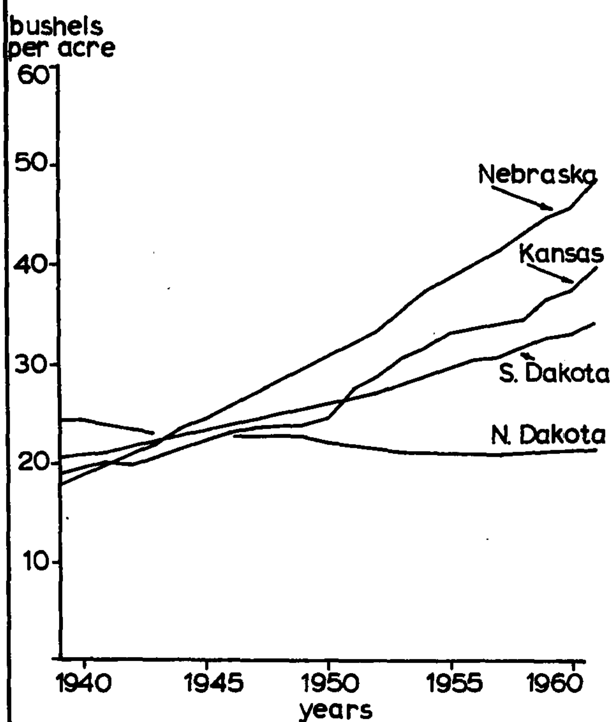


Figure 5.44. Exp. corn yields, N. Plains States, 1939-61

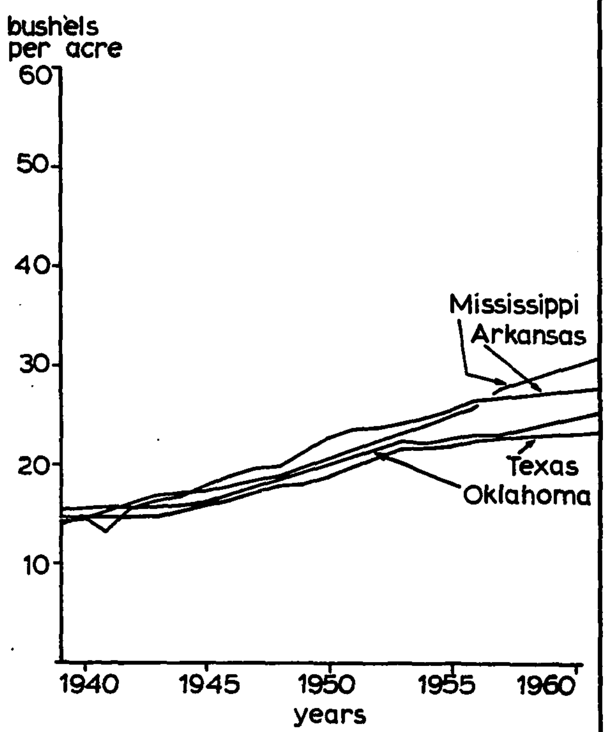


Figure 5.45. Exp. corn yields, S. Plains and Delta States, 1939-61

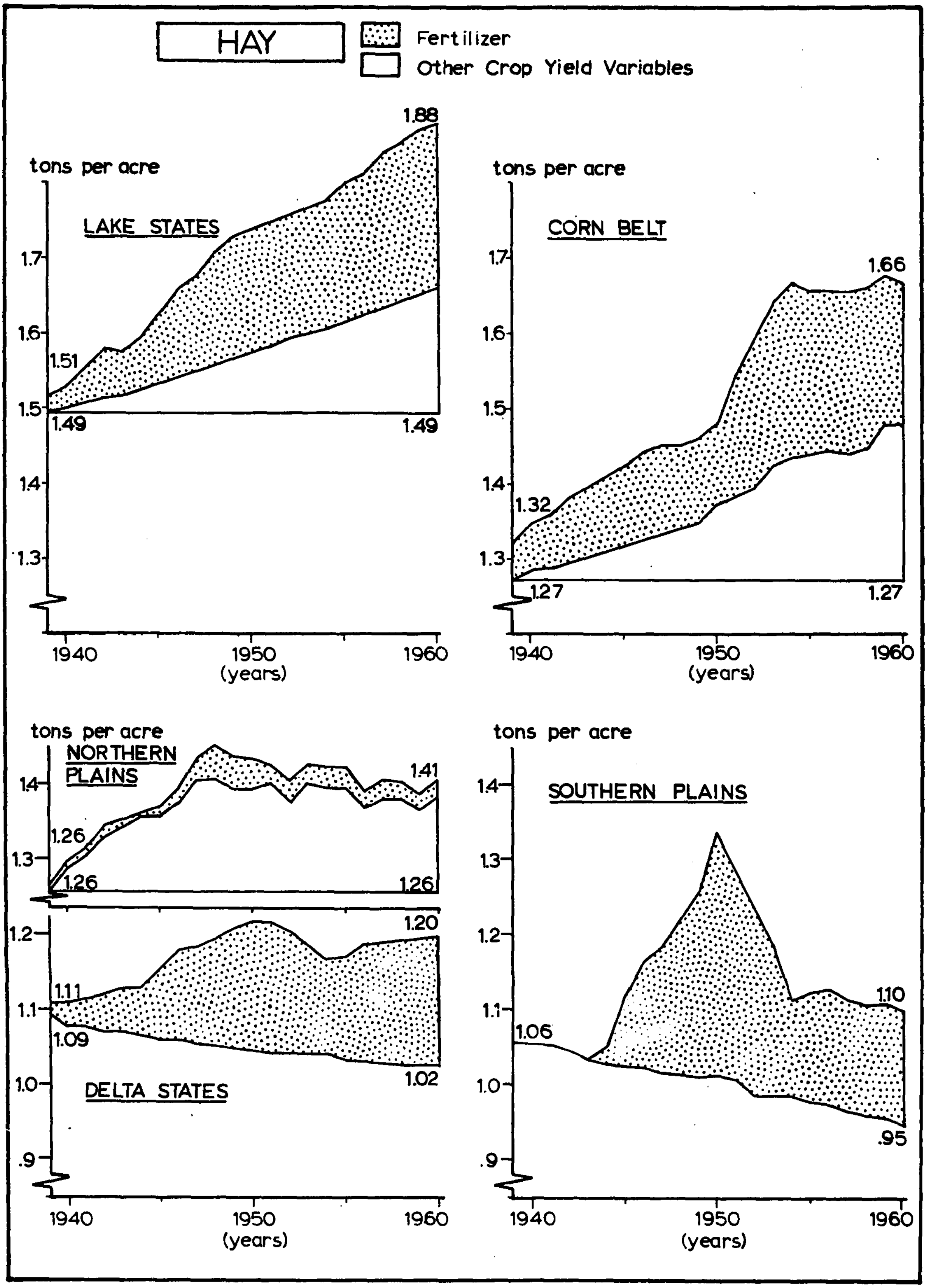
of corn hybrids accounted for most of the yield change. In Corn Belt and Delta States fertilization was the primary cause of higher yields, in the Lake States and Southern Plains introduction and adoption of new hybrids was the predominant force of yield improvement while yield increase in the Northern Plains was due to fertilization, hybrid improvement and other crop yield variables in equal measure (Figures 5.38, 5.39, 5.40, 5.41). In the Southern Plains effects of other crop yield variables had negative effects which, after allowance for fertilization and hybrid improvement, reduced net yield by 1.1 bushels over the 22 year period. In all other regions yield effects of unspecified crop yield variables were positive and especially strong in the Northern Plains region where a larger proportion of corn acreage was irrigated. For example in Nebraska, the most important corn producing State in the Northern Plains region, irrigated corn acreage expanded from approximately 329,000 acres in 1949 to 842,000 acres in 1959. The 1959 yield on irrigated corn acreage was 74.5 bushels compared to 44.3 bushels on nonirrigated land (49, p. 10). Corn yield differentials between regions were generally maintained, Corn Belt yields being highest and Southern Plains and Delta States yields being lowest over the entire time period. Some shifts occurred in yield relationships between states (Figures 5.42, 5.43, 5.44, 5.45). For example expected corn yields of Wisconsin, Illinois and Nebraska advanced in ranking order relative to other states of the same region. The shift in corn yield rank between Wisconsin and Minnesota could be attributed to higher rates of fertilizer application and greater improvements in corn hybrids. Illinois and Nebraska shifts were attributable to other crop yield variables. The Nebraska shift was

Figure 5.46. Tame hay yield change due to crop yield technology, Lake States, 1939 to 1960

Figure 5.47. Tame hay yield change due to crop yield technology, Corn Belt, 1939 to 1960

Figure 5.48. Tame hay yield change due to crop yield technology, Northern Plains and Delta States, 1939 to 1960

Figure 5.49. Tame hay yield change due to crop yield technology, Southern Plains, 1939 to 1960



HAY
Fertilizer
Other Crop Yield Variables
tons per acre
LAKE STATES
1.88
1.51
1.49
1.49
1.7
1.6
1.5
1.4
1.3
1940
1950
(years)
1960
tons per acre
CORN BELT
1.66
1.32
1.27
1.27
tons per acre
NORTHERN PLAINS
1.41
1.26
1.26
1.26
1.20
1.11
1.09
1.02
DELTA STATES
tons per acre
SOUTHERN PLAINS
1.10
1.06
.95

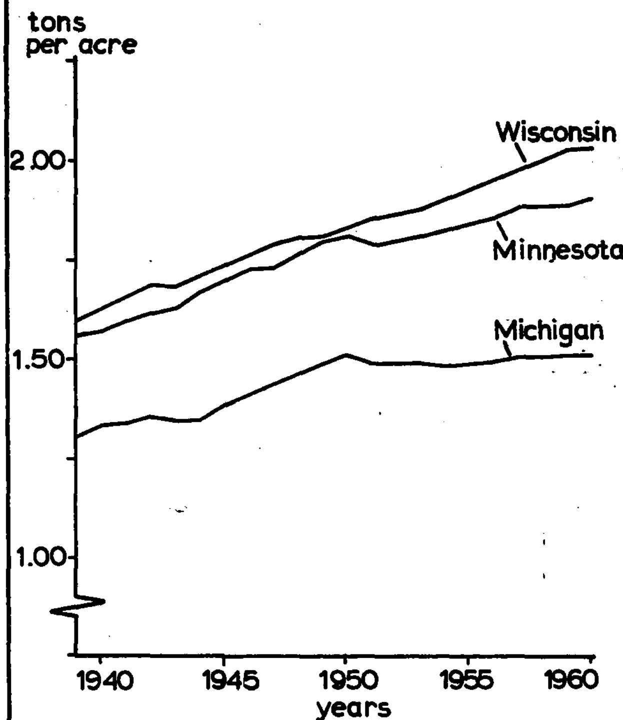


Figure 5.50. Exp. tame hay yields, Lake States, 1939-60

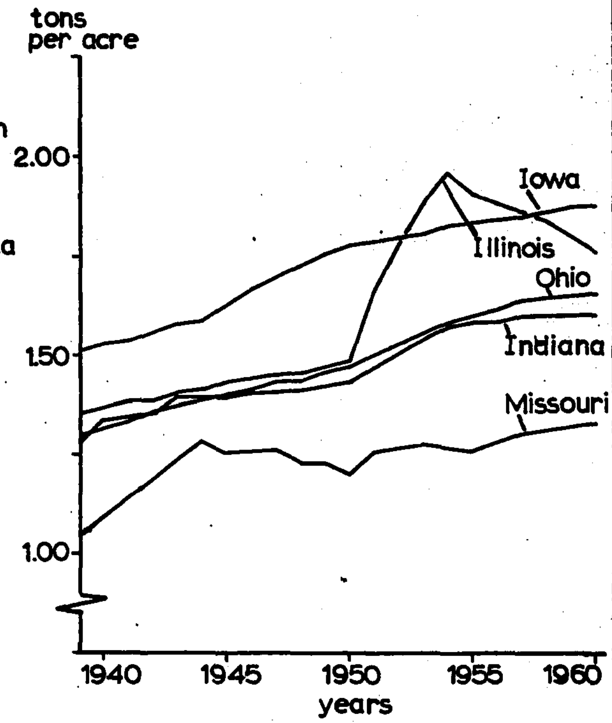


Figure 5.51. Exp. tame hay yields, Corn Belt States, 1939-60

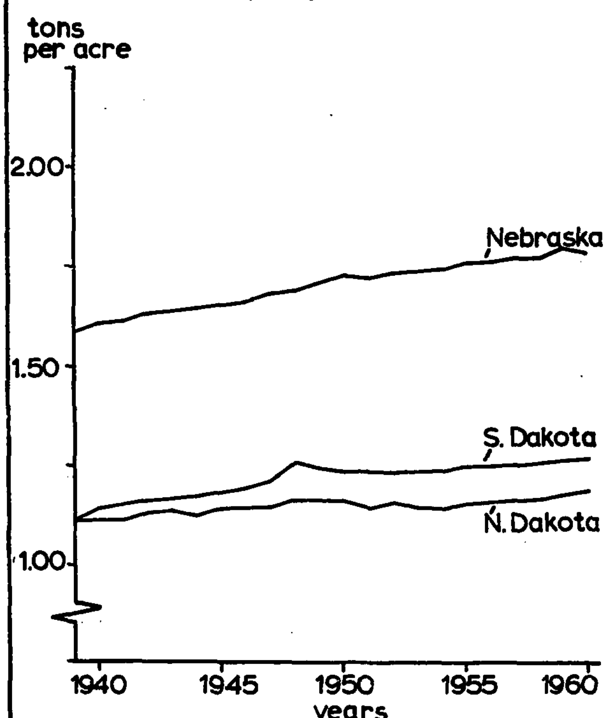


Figure 5.52. Exp. tame hay yields, N. Plains States, 1939-60

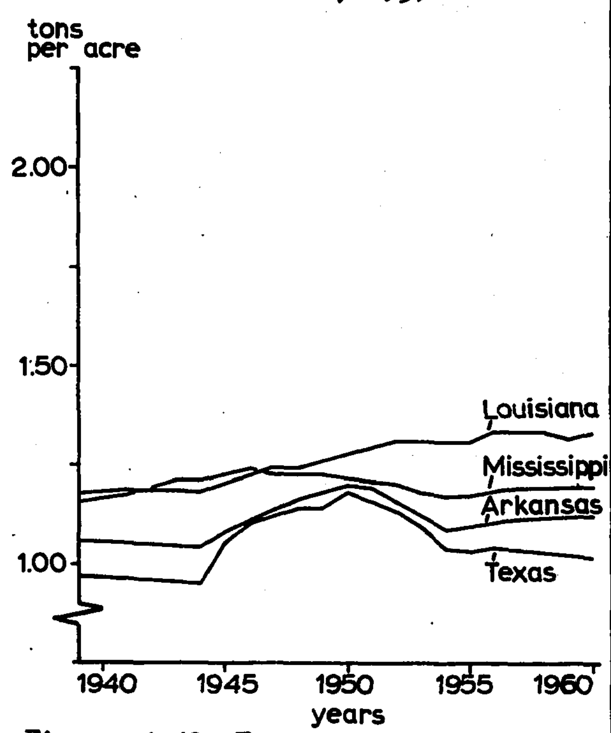


Figure 5.53. Exp. tame hay yields S. Plains and Delta States, 1939-60

probably due to irrigation practices being more rapidly adopted (in terms of corn acreage) than in other Northern Plains states (49, p. 10).

<u>Tame hay</u> Estimated tame hay yields increased in all regions but progress was irregular in most of them and quite unusual in Southern Plains states (Figures 5.46, 5.47, 5.48, 5.49). Over the period 1939 to 1960 average yields advanced by .36 and .35 tons in the Lake States and Corn Belt regions, by .14 tons in the Northern Plains and by less than .10 tons in Southern Plains and Delta States (Table 5.1). Yield increase was attributed to higher rates of fertilizer application and other unspecified crop yield variables. No index was computed to estimate effects of variety improvements or changes in relative acreages of differently yielding types of hay. As illustrated in Figures 5.50 to 5.53 expected hay yields of Lake States and Northern Plains states increased at fairly uniform rates while yields of some states in other regions displayed irregularities. In the Corn Belt tame hay yields of Missouri and Illinois reached peaks in 1944 and 1954, in the South Arkansas and Texas hay yields increased rapidly after 1944, declined after 1950 and then continued at a somewhat higher level. These irregularities could all be attributed to abrupt changes in estimates of fertilizer application. For example, Illinois N-P-K application rates were estimated at 2.8 pounds in 1951, 11.4 pounds in 1954 and 5.0 pounds in 1959. Since nutrient response coefficients were determined before regressing adjusted yields on other variables unusual patterns of hay yield curves of the states in question could be expected. No corrections were made for these abnormal estimates of application rates as they were adopted from original data sources and could not be

changed if standard procedures of estimation employed in this study were to be followed. Considering that application rates for more than 80 state crops were presented here it is apparent that irregularities as encountered in the tame hay analysis were exceptional.

Impact of Crop Yield Technology and Production Location on Aggregate Yields and U.S. Crop Production

Estimation of aggregate crop yield change requires that crop yield effects of production location are taken into account. Consideration of production location effects on crop yields would be superfluous if crop yields had been identical in all states. In the preceding sections it was shown that there were notable differences of crop yields between regions as well as among states within regions. But differences in state crop yields alone or differences in rates of change of crop yields over time do not necessitate analysis of yield effects of production location. If yields differed between states but state crop acres remained constant over time aggregate crop yields of all states could be computed by adding state crop yields weighted by relative state crop acres. Effects of production location on aggregate crop yields must be considered if relative state crop acres change over time. Evidence of change in relative state crop acres over time will be presented later, first a procedure for estimating production location effects on aggregate crop yields will be discussed.

Estimation procedures of production location effects were based on methods used for analysis of changes in crop yield technology earlier. Year to year yield changes were attributed to different technologies according to formula 5.5 earlier in this chapter. For estimating aggregate yield effects one additional variable, measuring yield effects of changes in production location, was required. Aggregate crop yield aY of m states in year j is defined by 5.8 as the sum of state crop yields Y_{ij} weighted by relative state acreage R_{ij}. Relative state crop acreage is state crop

$$aY_j = \sum_i^m Y_{ij} R_{ij} \quad \text{where } R_{ij} = A_{ij} \Big/ \sum_i^m A_{ij} \tag{5.8}$$

$$\Delta aY_j \sim \sum_i^m \left(\left(\frac{\partial aY}{\partial V_i}\right)_j \Delta V_{ij} + \left(\frac{\partial aY}{\partial F_i}\right)_j \Delta F_{ij} + \left(\frac{\partial aY}{\partial T_i}\right)_j \Delta T_{ij} + \left(\frac{\partial aY}{\partial R_i}\right)_j \Delta R_{ij}\right) \tag{5.9}$$

$$\Delta aY_j \sim \sum_i^m \left(\frac{\partial Y_i}{\partial V_i}\right)_j \Delta V_{ij} R_{ij} + \sum_i^m \left(\frac{\partial Y_i}{\partial F_i}\right)_j \Delta F_{ij} R_{ij} + \sum_i^m \left(\frac{\partial Y_i}{\partial T_i}\right)_j \Delta T_{ij} R_{ij} + \sum_i^m \left(\frac{\partial Y_i}{\partial R_i}\right)_j \Delta R_{ij} \tag{5.10}$$

acreage A_{ij} divided by the sum of all m state crop acreages. The right hand side of equation 5.8 is equivalent to the sum of m state crop production function estimates. Applying a first term Taylor expansion analogously to formula 5.5 approximates change in aggregate crop yield as in 5.9. Individual terms of the sum in 5.9 are partial derivatives of aggregate crop yield with respect to crop variables of state i at year j multiplied by change in value of the same variables from year j to j+1. Partial derivatives of aggregate crop yield change, e.g. $(\partial aY/\partial V_i)_j$, are equal to partial derivatives of state crop yield change multiplied by R_{ij}, e.g. $(\partial Y_i/\partial V_i)_j$, because all state crop production functions are of exponential form and multiplied by R_{ij} as indicated by 5.8 and 5.10. The last term in 5.10 specifies change in aggregate crop yield attributable to change in production location. It is the sum of partial derivatives with respect to relative state crop acreage R_{ij} multiplied by change in relative crop acreage $\triangle R_{ij}$ of state i between year j and j+1. On the basis of approximation 5.10 annual aggregated crop yield change was attributed to variety improvement, change in fertilization practices, changes in other (unspecified) crop yield variables and production location effects. Approximate values of individual terms in 5.10 were adjusted annually to make approximation 5.10 an equality. Again adjustments required in empirical analysis were usually small, e.g. less than 5 percent of annual yield change, except when year to year changes in relative crop acres were large or yield change approached zero.

Relative crop acreages changes between states, regions and crops over time. As was demonstrated previously crop yields differed between states and regions and crop yields of individual states advanced at different rates over time. Without long run changes in relative state acres long run effects of production location on aggregated crop yields would have been unlikely. A gain in aggregate crop yield due to a shift in production from lower to higher yielding areas in one particular year might easily be lost by a shift in the opposite direction in a later year. On the other hand more permanent yield effects could be expected if long run acreage trends existed between areas of different inherent productivity and different productivity trends over time. First indications of possible long run effects of production location on aggregate crop yields can be gained from Table 5.3. In this Table regression coefficients of linear time trend lines of state crop acreages are listed. All regression estimates are comparable as they cover the same time period from 1939 to 1960[1]. In the exceptional case of grain sorghums regression lines were fitted to state acres over the years 1950 to 1960 but connected to average annual acres of the years 1939 to 1949 because grain sorghum acreages remained fairly constant during the earlier period and expanded rapidly during later years. Regional acreage trend coefficients were computed by adding state acreage trend coefficients, a permissable procedure as all state regressions were fitted over identical time periods.

Production location effects were estimated for all crops on short and long run basis. Short run estimates were based on annual changes, long run estimates were derived by cumulative short run changes. Impact of crop yield technology and production location effects on aggregate crop production as well as reliability of aggregate estimates and significance in relation to U.S. crop production are presented diagrammatically in Figures 5.54 to 5.77 and discussed next.

Wheat   Characteristics of harvested wheat acreage trends are listed in Table 5.3. The a-values in column 1 represent estimated 1939 acreage (in 1000 acres), b-values in column 2 can be interpreted as annual change in trend acres (in 1000 acres) and r^2-values in column 3 measure (on state basis) strength of acre-time trend relationships. According to estimates in Table 5.3 harvested state wheat acreages changed at different rates. In Michigan and Illinois wheat acreage expanded, in South Dakota and Nebraska winter wheat replaced some of the spring wheat acreage and

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[1]These regression estimates were required for estimation of acreage indices which measured short run deviations from acreage trends, they were not used for estimation of production location effects.

Table 5.3. Estimated harvested crop acreage trends by states and regions, 1939 to 1960

Crop	Region State	Estimated Coefficients a[a] (1)	b (2)	r^2 (3)
Wheat 1939-60	Lake States	3259.2	-15.8	
	Mich.	836.8	19.4*	.28
	Wisc.	93.4	-1.5*	.23
	Minn.	1429.0	-33.7**	.65
	Corn Belt[b]	5226.5	-20.9	
	Ohio	2081.7	-22.3+	.18
	Ind.	1452.0	-5.9	.03
	Ill.	1440.3	13.4	.09
	Iowa	252.5	-6.1*	.21
	N. Plains[c]	12695.8	-145.8	
	N. Dak.	9419.3	-91.3	.15
	S. Dak.	3161.7	49.3	.19
	Nebr.	114.8	-5.2**	.74
	N. Plains[d]	15223.8	-46.7	
	S. Dak.	119.0	17.7**	.78
	Nebr.	3157.6	20.4	.05
	Kans.	11947.2	-84.8	.06
	S. Plains	9420.4	-86.0	.09
	Texas	4382.2	-69.5-	.01
	Okla.	5038.2	-16.5-	.01
Oats 1942-60	Lake States	8638.4	-20.26	
	Mich.	1390.8	-19.47**	.35
	Wisc.	2604.4	8.86-	.05
	Minn.	4643.2	-9.65-	.01

**Tested statistically significant at the one percent level.

*Tested statistically significant at the five percent level.

+Tested statistically significant at the ten percent level.

-Did not test statistically significant at the ten percent level.

[a]Estimated 1939 acreage.

[b]Excluding Missouri.

[c]Spring wheat area, excluding Kansas.

[d]Winter wheat area, excluding North Dakota.

Table 5.3. (Continued)

Crop	Region State	Estimated Coefficients a[a] (1)	 b (2)	 r^2 (3)
Oats 1942-60	Corn Belt	13361.6	-142.72	
	Ohio	1105.2	.47-	.01
	Ind.	1314.7	-14.08*	.26
	Ill.	3571.4	-50.80**	.40
	Iowa	5477.8	-13.33-	.02
	Mo.	1892.5	-64.98**	.77
	N. Plains	8308.4	-39.38	
	N. Dak.	2104.3	-14.24-	.09
	S. Dak.	2608.2	41.85+	.17
	Nebr.	2099.7	-19.11-	.07
	Kans.	1496.2	-47.88**	.60
	S. Plains	2587.2	-62.91	
	Texas	1348.6	-14.42-	.06
	Okla.	1238.6	-48.49**	.60
Soybeans 1943-60	Lake States	410.6	148.43	
	Mich.	83.4	7.56**	.57
	Wisc.	31.1	3.67**	.60
	Minn.	296.1	137.20**	.89
	Corn Belt	6394.0	421.19	
	Ohio	851.8	33.28**	.62
	Ind.	1161.4	71.79**	.93
	Ill.	2899.8	126.48**	.86
	Iowa	1011.5	79.18**	.65
	Mo.	469.5	110.46**	.96
	Delta States[e]	169.8	148.76	
	Ark.	95.5	104.36**	.83
	Miss.	74.3	44.40**	.86
Barley 1943-60	Minn.	1362.4	-32.38*	.28
	N. Plains[f]	4746.3	-66.70	
	N. Dak.	2040.6	85.44**	.59
	S. Dak.	1630.7	-81.69**	.79
	Nebr.	1075.0	-70.45**	.61

[e]Excluding Louisiana.

[f]Excluding Kansas.

Table 5.3. (Continued)

Crop	Region State	Estimated Coefficients a^a (1)	b (2)	r^2 (3)
Flax 1944-60	Minn.	1341.2	-42.2**	.53
	N. Plains[g]	1666.9	130.6	
	N. Dak.	1252.0	106.3**	.58
	S. Dak.	414.9	24.3**	.56
Cotton 1939-60	S. Plains	9578.1	-129.3	
	Texas	8127.6	-70.2-	.07
	Okla.	1450.5	-59.1**	.80
	Delta States[e]	4408.5	094.4	
	Ark.	1981.5	-38.7**	.40
	Miss.	2427.0	-55.7**	.62
Grain Sorghum[h] 1939-60	N. Plains[i]	1444	436.1	
	Nebr.	166	134.8**	.86
	Kans.	1278	301.3**	.80
	S. Plains	4315	348.2	
	Texas	3637	334.1**	.76
	Okla.	678	14.1-	.15
Corn 1939-61	Lake States	8520.1	121.24	
	Mich.	1530.4	20.19**	.62
	Wisc.	2346.0	21.64**	.61
	Minn.	4644.5	79.41**	.61
	Corn Belt	29367.8	193.61	
	Ohio	3391.4	8.52-	.10
	Ind.	4058.0	44.82**	.64
	Ill.	7929.3	76.88**	.47
	Iowa	9704.9	82.09**	.32
	Mo.	4284.2	-18.70+	.14
	N. Plains	15113.5	-76.99	
	N. Dak.	1080.4	12.52**	.60
	S. Dak.	3166.3	53.16**	.54
	Nebr.	7692.2	-62.62*	.24
	Kans.	3174.6	-70.05**	.61

[g]Excluding Nebraska and Kansas.
[h]1939 estimates are average acres 1939-1949.
[i]Excluding N. Dakota and S. Dakota.

Table 5.3. (Continued)

Crop	Region State	Estimated Coefficients a[a] (1)	b (2)	r^2 (3)
Corn 1939-61	S. Plains	6663.2	-267.98	
	Texas	4710.5	-175.88**	.90
	Okla.	1952.7	-92.10**	.96
	Delta States	5164.6	-182.17	
	Ark.	2125.6	-90.05**	.97
	Miss.	3039.0	-92.12**	.98
Tame Hay 1939-60	Lake States	9839.9	-46.63	
	Mich.	2856.9	-43.36**	.86
	Wisc.	3982.5	-5.60-	.10
	Minn.	3000.5	2.33-	
	Corn Belt	14879.5	-117.11	
	Ohio	2676.5	-24.23**	.53
	Ind.	2054.0	-27.11**	.72
	Ill.	3059.8	-36.45**	.58
	Iowa	3465.6	10.23	.04
	Mo.	3623.6	-39.55**	.34
	N. Plains	1573.1	265.91	
	N. Dak.	632.2	61.56**	.71
	S. Dak.	138.2	120.57**	.81
	Nebr.	802.7	83.78**	.82
	S. Plains	2175.9	22.70	
	Texas	1320.2	10.29+	.16
	Okla.	855.7	12.41*	.27
	Delta States	2563.2	-44.17	
	Ark.	1338.1	-35.41**	.92
	Miss.	931.7	-14.04**	.83
	La.	293.4	5.28**	.54

wheat acreages of all other states declined at varying rates. In terms of annual acreage change the greatest decline occurred in the Northern and Southern Plains states, the least decline in Corn Belt and Lake States where expected yields were considerable higher, as indicated earlier. Due to a relatively greater decline of wheat acreage in lower yielding regions a positive aggregate yield effect could be expected. However, since most of the wheat was produced in the lower yielding Northern and Southern Plains it could also be anticipated that cumulative production location effects would be small. These expectations are confirmed by results presented in Figure 5.54 which illustrates aggregate wheat yield changes of all 13 states.[1] Greatest cumulative yield change was ascribed to increased fertilization. In 1960 expected wheat yield was estimated at 21.0 bushels, nearly a 50 percent increase since 1939 when expected yield was at 14.1 bushels. According to this analysis 0.7 bushels of the 14.1 bushels (14.1 bu. - 13.4 bu.) could be attributed to fertilizer use in 1939 compared to 3.3 bushels (21.0 bu. - 17.7 bu.) in 1960, a net increase of 2.4 bushels due to more extensive fertilizer use. Cumulative changes in aggregate wheat yield due to variety improvement and other crop yield variables were estimated at 2.1 bushels each. Cumulative production location effects accounted for only 0.1 bushels in 1961. During earlier years of the period of analysis production location effects were negative due to a shift in production to power yielding regions. Occurrence of negative effects of production location is a contradiction of positive effects suggested by

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[1]State analyses of spring and winter wheat were included individually but only counted once.

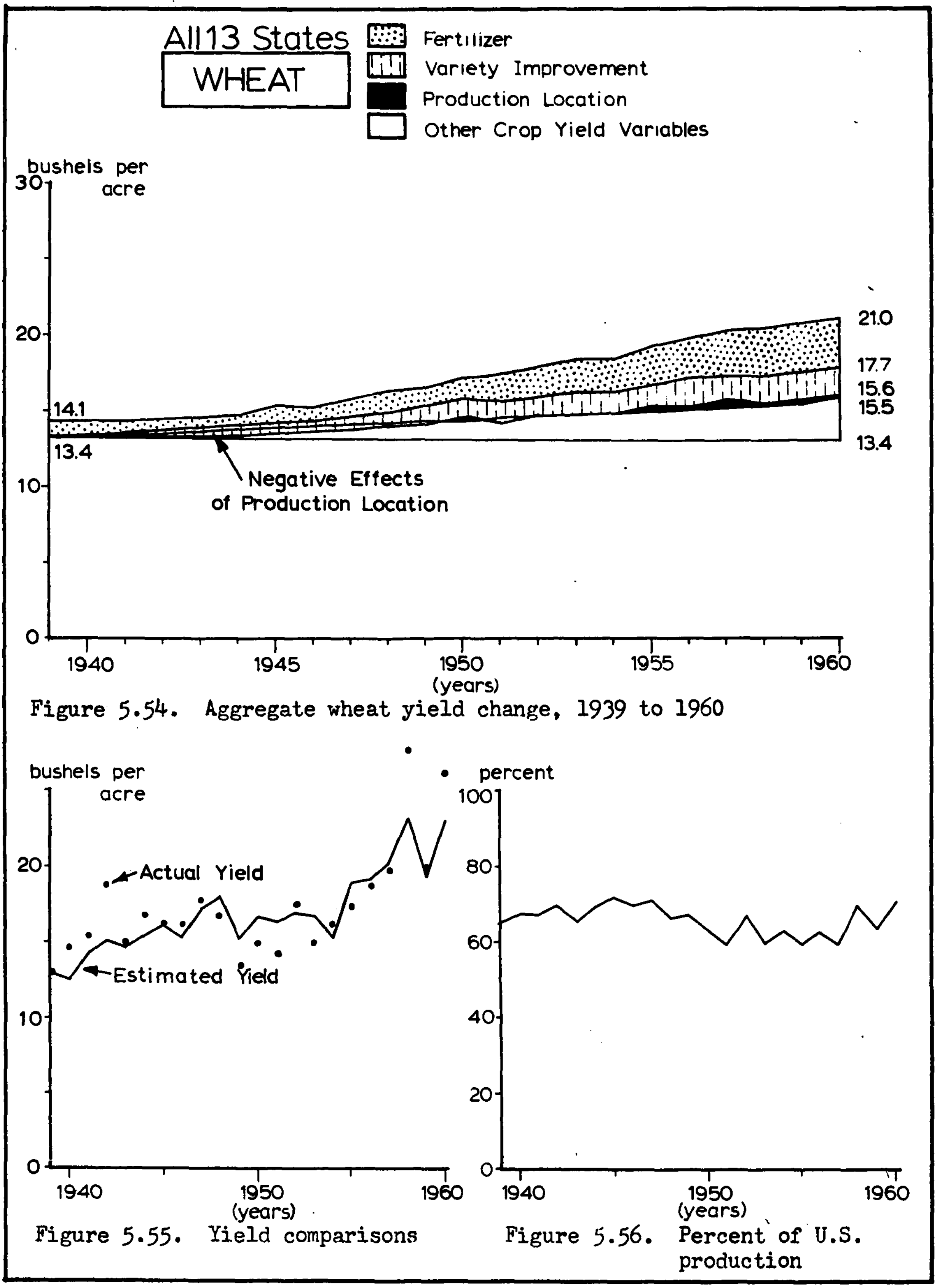

Figure 5.54. Aggregate wheat yield change, 1939 to 1960

Figure 5.55. Yield comparisons

Figure 5.56. Percent of U.S. production

long run state acreage trends but this analysis attributes comulative effects of shifts in production location on annual rather than long run basis, the reason for this discrepancy. Closer agreement between anticipated and estimated effects could have been expected if correlation indices (r^2) of time trend lines of state wheat acreages had been greater.

In Figure 5.55 actual and estimated yields[1] are compared in aggregate. Evidently estimates differed greatly from actual yields in 1942, 1958 and 1960. These differences were caused by significant deviations of estimated from actual wheat yields for the same years in Kansas, the most important wheat producing state. As was shown in the summary of estimated state crop production functions (Table 4.8) the Kansas wheat weather index did not test statistically significant at the 1.0 percent level of significance and it is likely that these deviations can be attributed to inferior weather index estimates rather than unidentified variables of technological change. Aside from these large deviations actual yields were lower than estimated yields from 1948 to 1951 but higher from 1940 to 1947 and again from 1958 to 1959. Except for the three years mentioned earlier these deviations are quite small but might be an indication of effects of other crop yield variables not quantified in the analysis. - Figure 5.56 illustrates what proportion of annual U.S. wheat production was analyzed by state wheat production function analysis. Evidently it covered from 60 to 70 percent of U.S. wheat production in most of the years. Even though it implies that results of this analysis reflect the impact of crop yield

[1]Estimated yields were computed from annual data sets and state crop production functions. Estimated crop yields differ from expected crop yields as they incorporate annual acreage and weather effects whereas the latter do not.

technology on most of U.S. wheat production it can only be taken as an approximation as one third of production was not analyzed.

Oats Effects of crop yield technology on aggregate oats yields are pictured in Figure 5.57. Expected oats yields increased from an estimated 33.6 bushels per acre in 1942 to 37.0 bushels in 1960. Most of the aggregate yield change was attributed to variety improvement, followed by fertilizer use and a positive but small cumulative effect of 0.9 bushels per acre due to production location. According to Table 5.3 this positive acreage effect was likely due to less than average reduction in oats acreage of higher yielding states such as Minnesota, Indiana, Iowa and positive, but statistically insignificant, acreage changes in Wisconsin and Ohio. Also greater than average reduction of lower yielding Missouri oats acreage might have contributed to positive aggregate yield effects. However, long run trends of oats acreages can only serve as tentative indicators because correlation coefficients of acreage trends were low in most cases and cumulative acreage effects were computed on annual basis as pointed out earlier. Negative effects of other oats yield variables reduced the 9.0 bushel gain[1] to 37.0 bu. - 33.6 bu. = 3.4 bu. - Actual and estimated oats yields are shown in aggregate in Figure 5.58. Except for the year 1953 and 1958 estimated and actual yields are fairly close presumable because weather indices of major oats producing states, e.g. Iowa, Illinois, tested statistically significant at 1 percent levels. According to Figure 5.59 the oats analysis encompassed about 85 percent of U.S. oats production over the years 1942 to 1960. Even though oats

[1]The 9.0 bushels gain in aggregated oats yields is defined by the following yield differences: (37.0 bu. - 26.9 bu) - (33.6 bu. - 32.5 bu.).

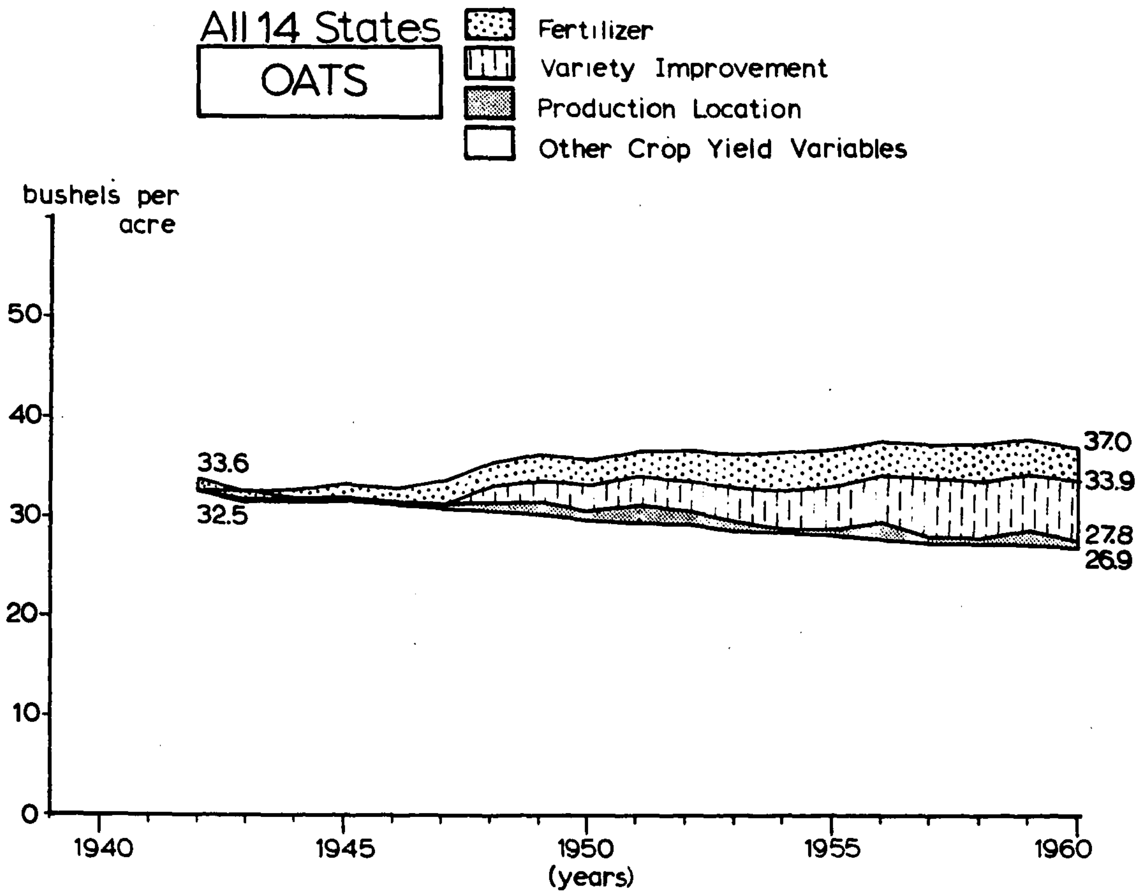

Figure 5.57. Aggregate oat yield change, 1942 to 1960

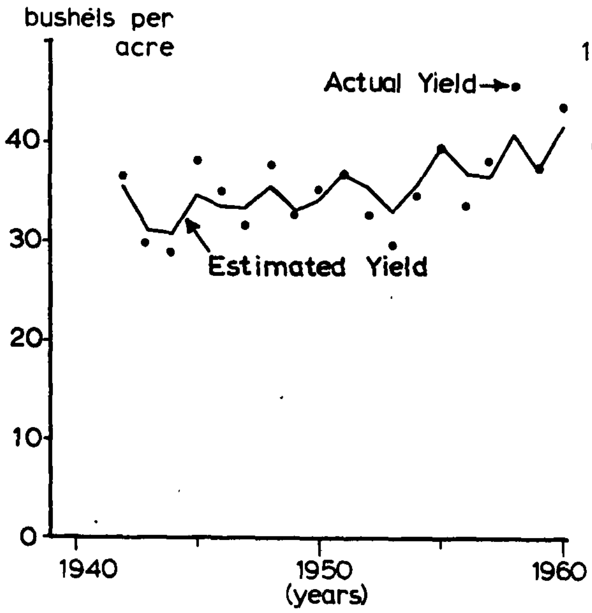

Figure 5.58. Yield comparisons

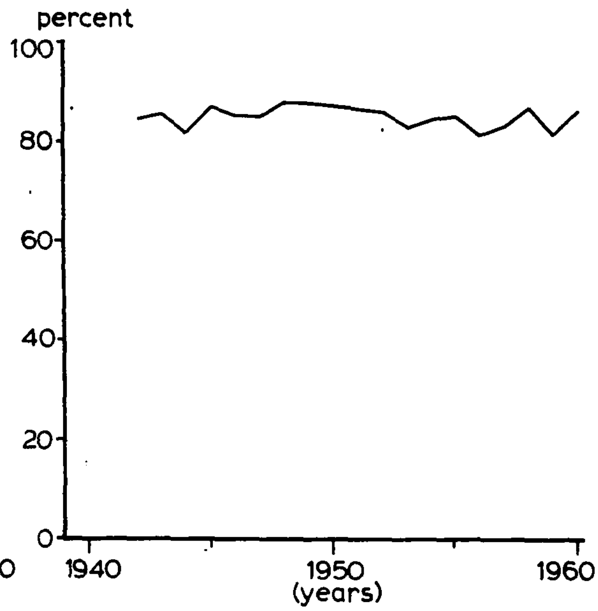

Figure 5.59. Percent of U.S. production

production is of declining importance as reflected by significant acreage reductions, particularly during more recent years, it would be of interest to determine specifically what crop yield variables caused negative yield effects.

<u>Soybeans</u> In discussing state crop production functions in Chapter IV it was pointed out that coefficients of soybean acreage indices were quite consistently negative. It was suggested at the time that soybeans appeared to be sensitive to short run acreage expansion. Results of aggregate soybean analysis indicate that the same holds true for long run acreage expansion. As shown in Figure 5.60 expected soybean yields increased in aggregate from 19.2 to 23.3 bushels, an increase of 4.1 bushels or 21 percent over 17 years. Percentage estimates of regional change were more than twice as large ranging from 42.0 to 56.3 percent (Table 5.2) and yield effects of other soybean yield variables were not negative but positive for all regions (Figures 5.19 to 5.21). In the aggregate other crop yield variables raised soybean yields from 18.8 to 19.6 bushels but negative production location effects reduced yields from 19.6 to 18.2 bushels. Aggregate yields would have exceeded 25 bu. per acre if expansion of acreage would not have cancelled part of the gains achieved through variety improvement, an indication that acreage expansion had negative effects on soybean yields over short as well as long run periods. Fertilizer yield response of soybeans was quite small, usually application rates were low and only .9 bushels of aggregate yield change were attributed to increased fertilizer application. - Estimated soybean yields were fairly close to actual yields with three exceptional years (Figure 5.61).

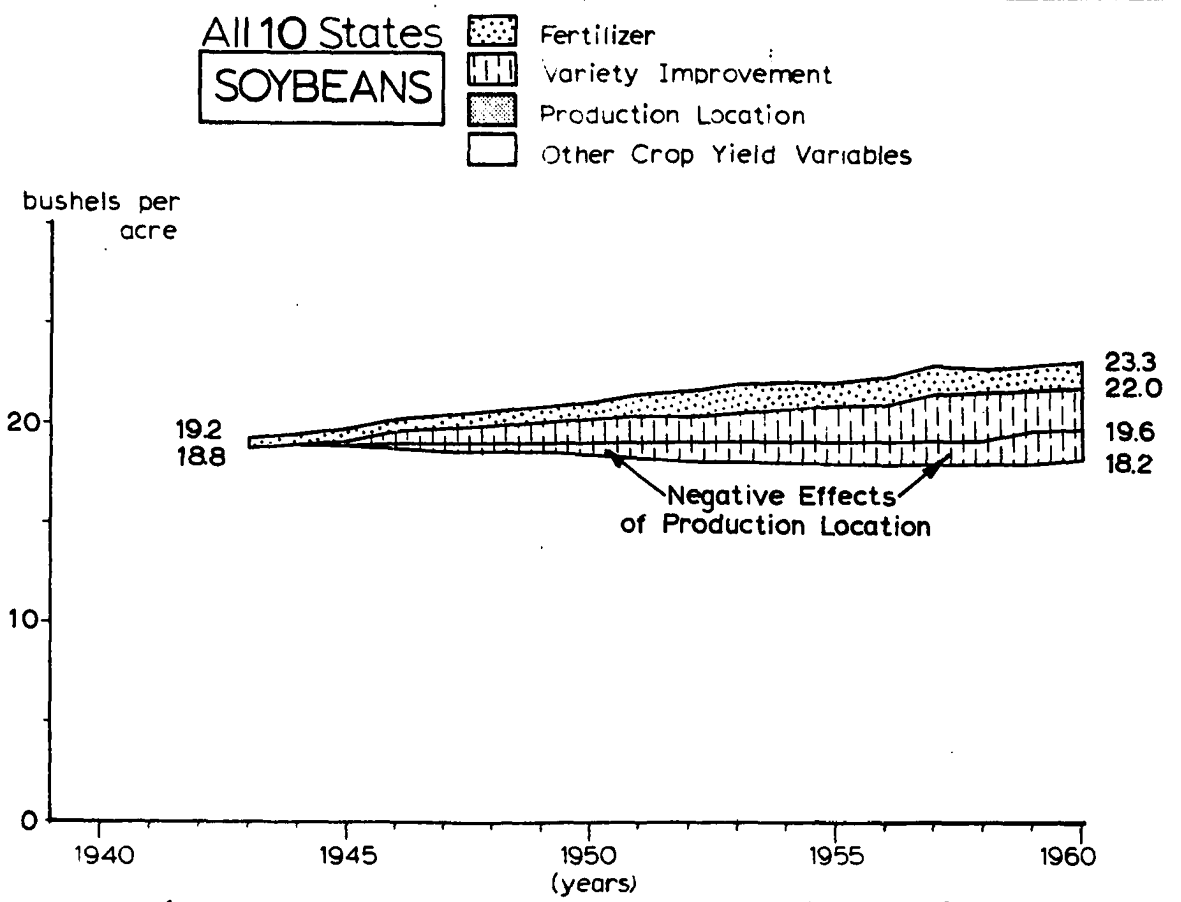

Figure 5.60. Aggregate soybean yield changes, 1943 to 1960

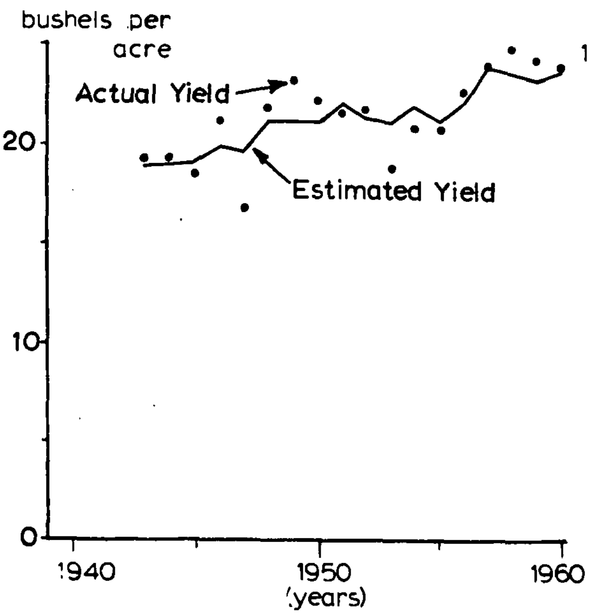

Figure 5.61. Yield comparisons

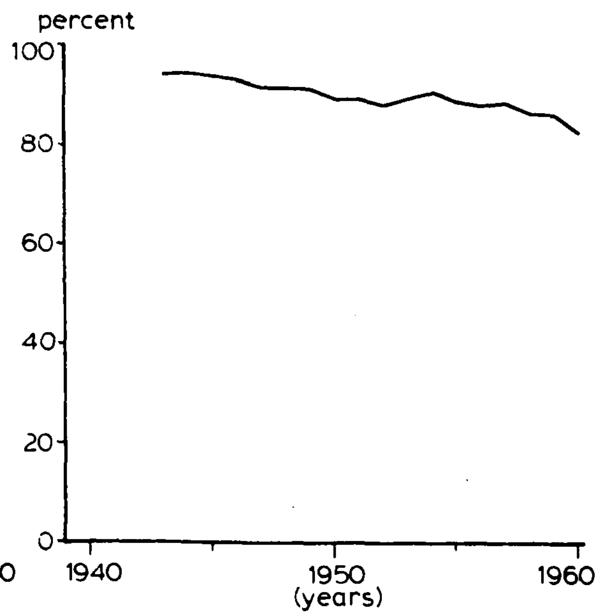

Figure 5.62. Percent of U.S. production

Considering that on the average only two thirds of annual soybean yield variations could be explained by variables included in the state crop production functions, aggregate results appeared to be quite satisfactory. During earlier years soybean production of the ten states included in the analysis made up approximately 95 percent of total U.S. production, but over time this ratio declined by more than 10 percent, as soybean acreage spread to other regions.

Barley, flax, cotton and grain sorghum Characteristics of aggregate change in barley yields are depicted in Figures 5.63 to 5.65. As is evident from Figure 5.65 the analysis covered about 40 percent of U.S. production over the years 1943 to 1948 but then dropped to the 30 percent level where it settled during the later fifties. In view of this comparatively low coverage impact of yield technology, production location and concurrence between actual and estimated crop yields is closer related to production in the Northern Plains area than total U.S. production. Expected yields increased from 20.6 bushels to 25.1 bushels from 1943 to 1960. A 1.4 bushel yield increase was attributed to increased fertilizer use, a 2.4 bushel yield increase was ascribed to adoption of superior varieties in recent years and practically all the remaining increase resulted from changes in production location. Relative barley acreage shifted towards the higher yielding Minnesota area during the late forties and early fifties but shifted back again to the lower yielding Northern Plains area in later years. Therefore effects of production location first increased and later decreased aggregate barley yields. Other crop yield variables had little effect on aggregate yield because strong positive yield effects of the smaller Minnesota area were cancelled out by slightly

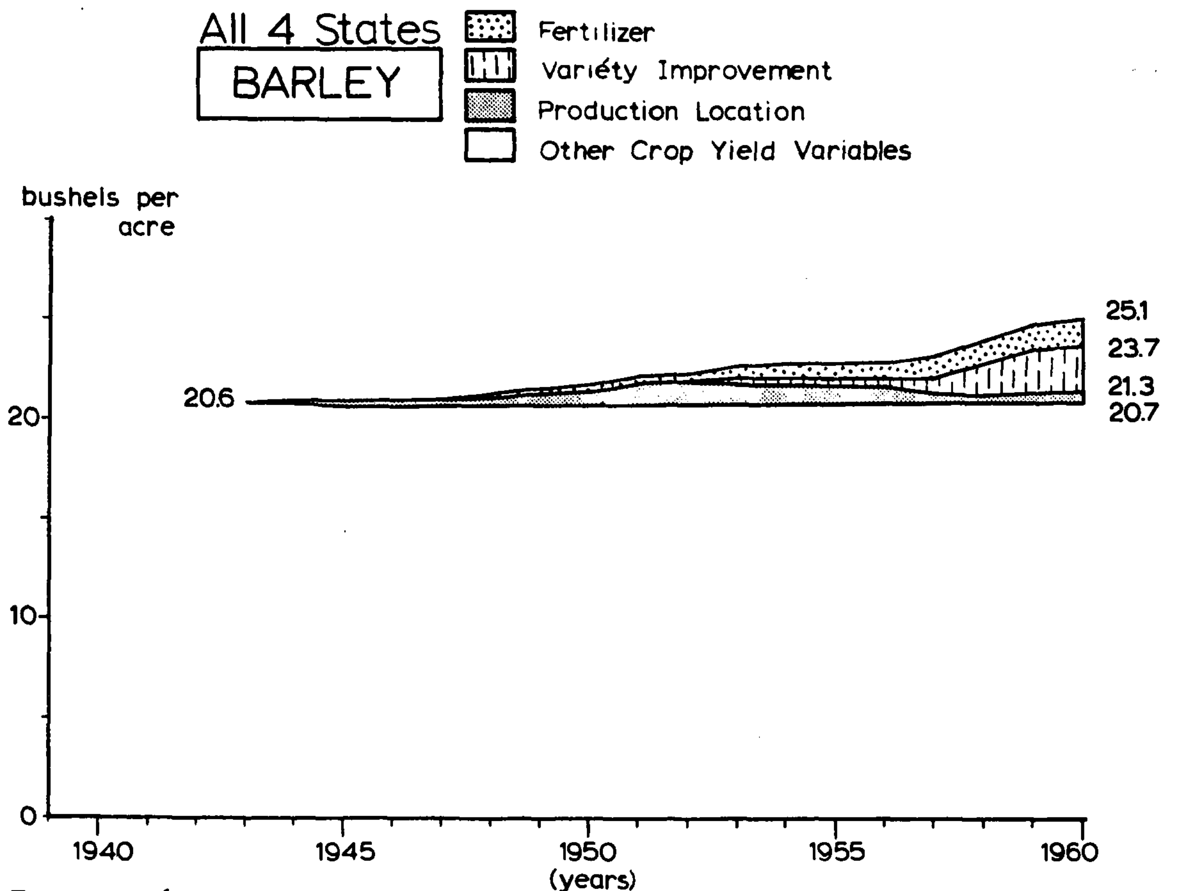

Figure 5.63. Aggregate barley yield change, 1943 to 1960

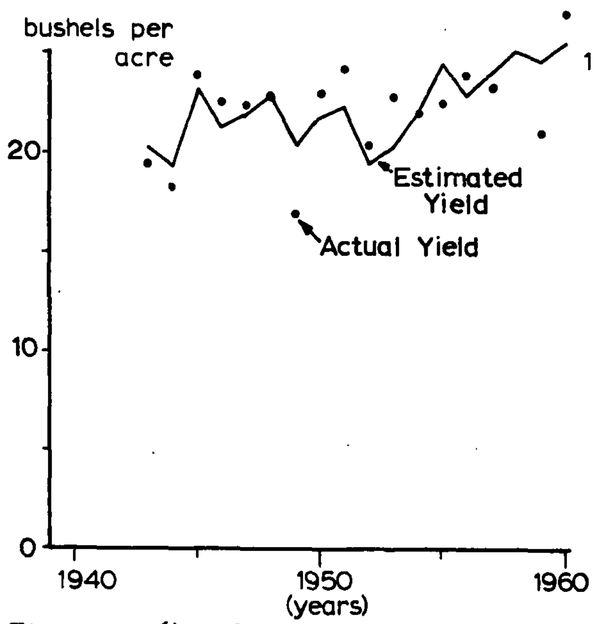

Figure 5.64. Yield comparisons

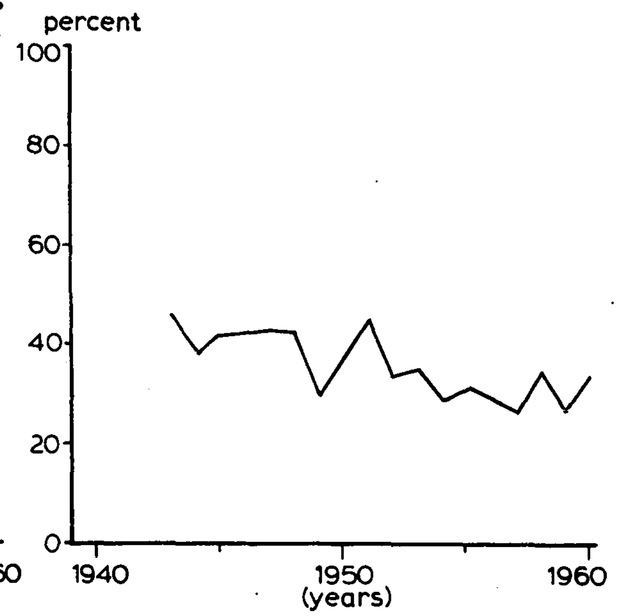

Figure 5.65. Percent of U.S. production

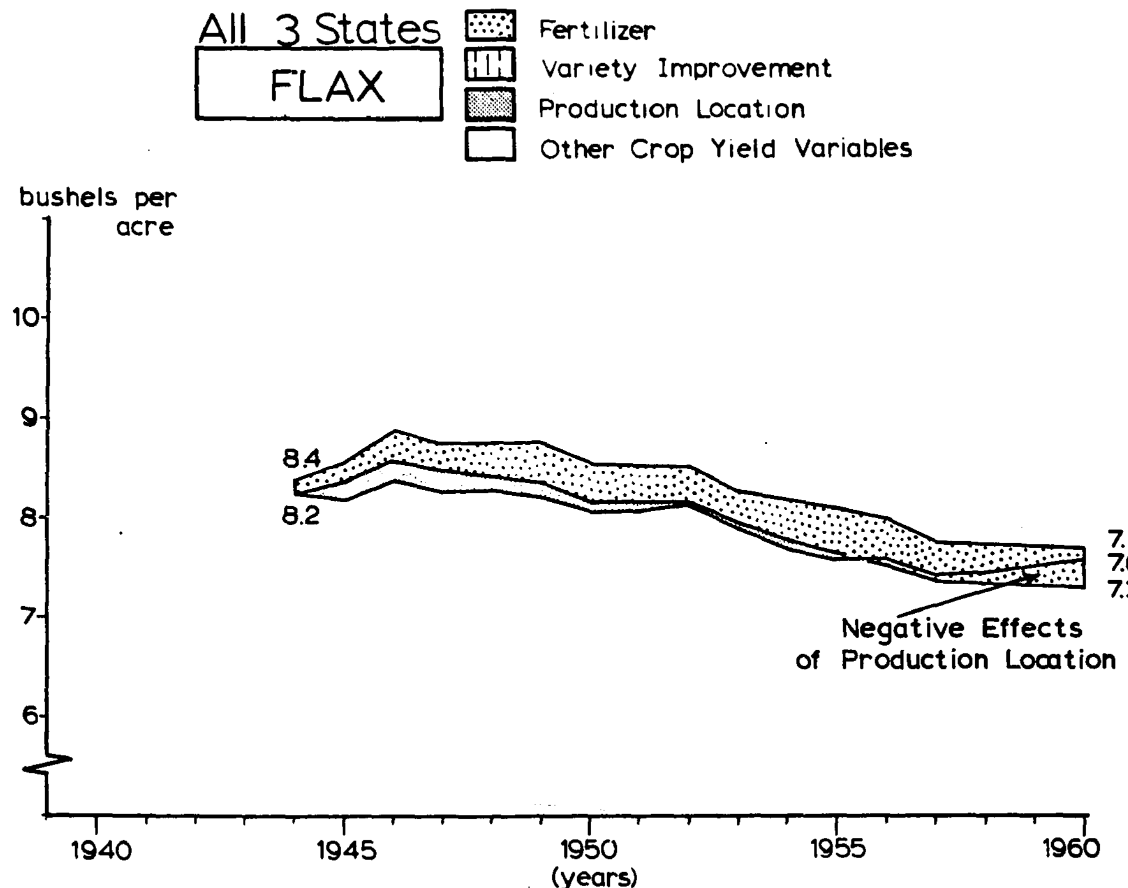

Figure 5.66. Aggregate flax yield change, 1944 to 1960

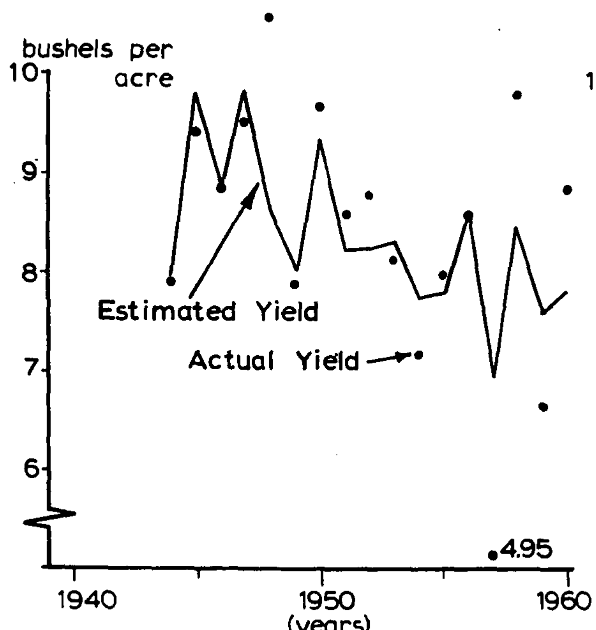

Figure 5.67. Yield comparisons

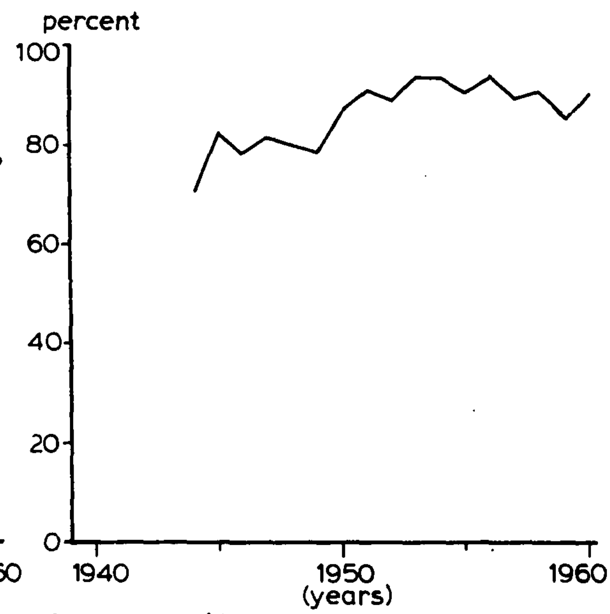

Figure 5.68. Percent of U.S. production

negative effects of the larger Northern Plains area. Actual and estimated barley yields differed markedly in the years 1949, 1958 and 1959 and actual yields were higher than estimated yields from 1950 to 1954 a four year deviation which may or may not have been caused by random errors in annual weather indices.

Flax production of only three states was analyzed but in most years the analysis covered from 80 to 90 percent of U.S. production (Figure 5.68). Aggregate flax yields first rose above the 1944 yield of 8.4 bushels but then dropped to 7.7 bushels (Figure 5.66). The initial rise in expected yields was partly caused by production location effects due to a relative increase in Minnesota flax acreage but lost in later years when flax acreage expanded in the Northern Plains area as reflected in large positive acreage trend line coefficients of flax acreage of the Dakotas (Table 5.3). Decline in variety index values, somewhat lower rates of fertilizer application and slightly negative effects of other crop yield variables contributed to the reduction in aggregated yields. As shown in Figure 5.67 flax yields fluctuated widely over the years, from a high of 10.56 bushels in 1948 to a low of 4.95 bushels in 1957. Year to year variations of estimated flax yields are less pronounced than those of actual yields but deviations of actual from estimated yield appear to be randomly distributed.

Characteristics of aggregate cotton yields are illustrated by Figures 5.69 to 5.71. Yields advanced from 192.4 pounds in 1939 to 354.3 pounds in 1960. A large portion of the yield increase was attributed to other unspecified crop yield variables, primarily as a result of production function estimates of Texas cotton yields. Increased fertilizer use and

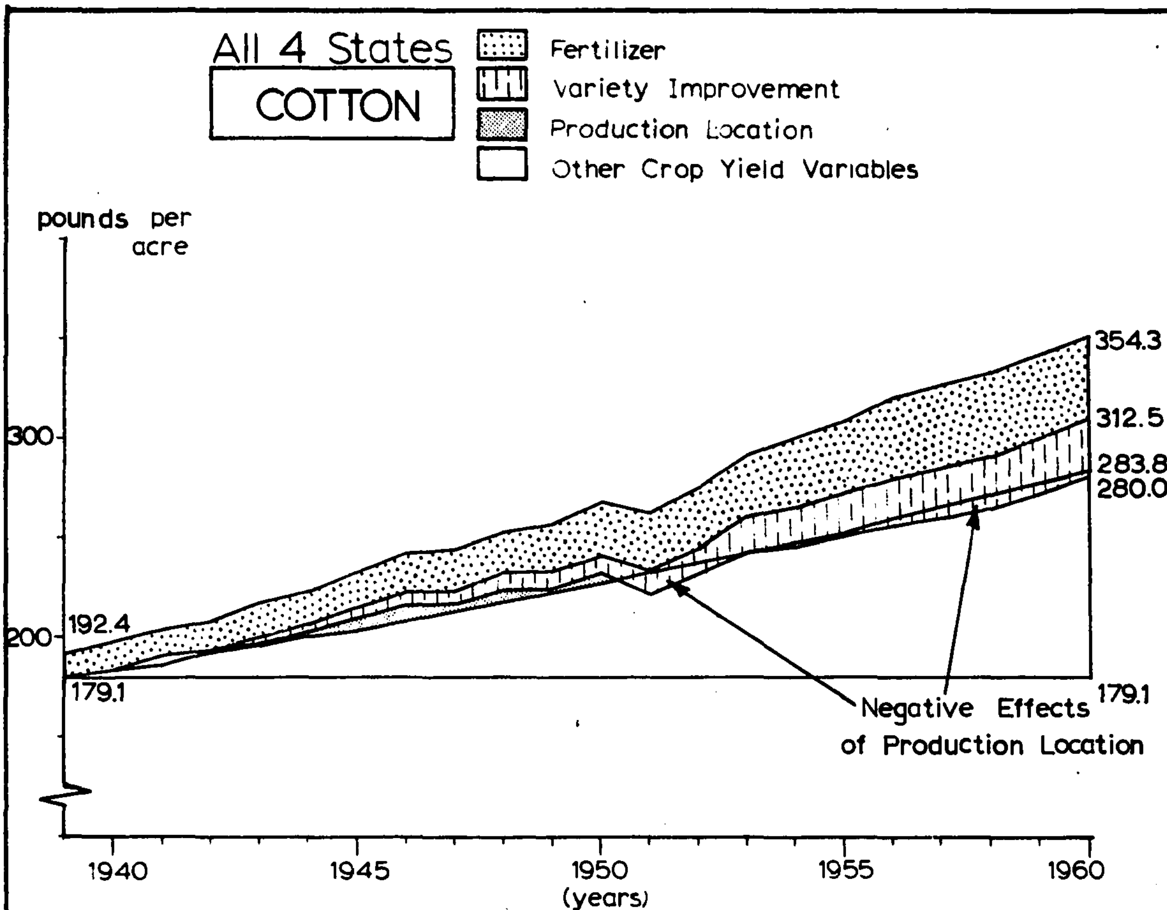

Figure 5.69. Aggregate cotton yield change, 1939 to 1960

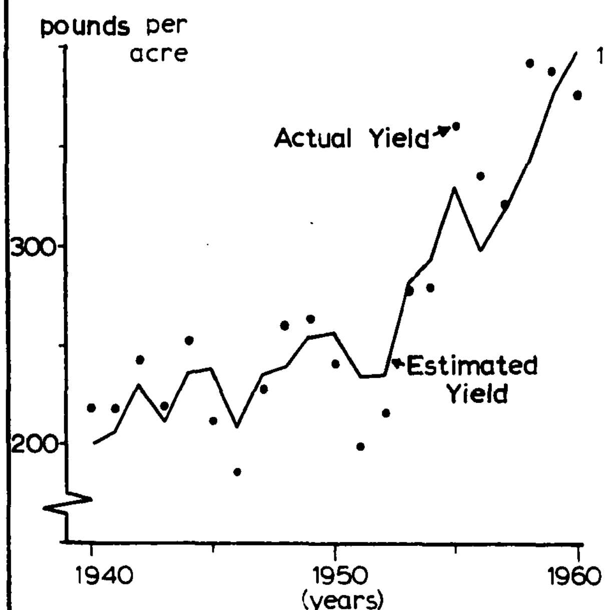

Figure 5.70. Yield comparisons

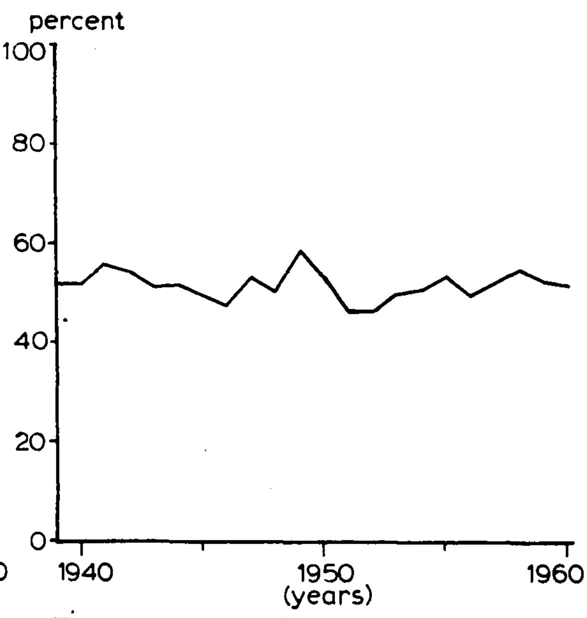

Figure 5.71. Percent of U.S. production

cotton variety improvements contributed significantly to the rise in cotton yields. Production location effects were positive during the early period, turned abruptly down in 1951 and were negative from thereon. The downturn from positive to negative production location effects on aggregate cotton yields was caused by a sudden shift in favor of the lower yielding production area of the Southern Plains where cotton acreage expanded from 7.5 million acres in 1950 to 13.3 million acres in 1951. Reversed acreage shifts in later years were not strong enough to overcome negative production location effects of earlier years. Correlation between actual and estimated aggregate cotton yields appeared to be quite close, perhaps closer than conveyed by Figure 5.70 where the vertical yield scale is enlarged considerably. According to Figure 5.71 the cotton analysis comprised about 50 percent of U.S. production and consequently much of the yield increase caused by production location shifts from the cotton area of the southeast (short staple cotton varieties) to irrigated cotton areas (long staple cotton varieties) of Arizona, New Mexico and California is not taken into account here.

Aggregate grain sorghum yields more than doubled since 1939 and most of the change occurred during the last decade. Expected yields rose from 14.9 bushels in 1939 to 33.3 bushels in 1960, an increase of 18.4 bushels of which 6.7 bushels were attributed to adoption of sorghum hybrids, 3.1 bushels to fertilizer use and 1.0 bushels to production location effects. A large portion of the yield increase, 7.6 bushels, was ascribed to unspecified crop yield variables. Irrigated grain sorghum acreage in Texas expanded from ca. 13 percent in 1949 to ca. 24 percent in 1959 (49, p. 12)

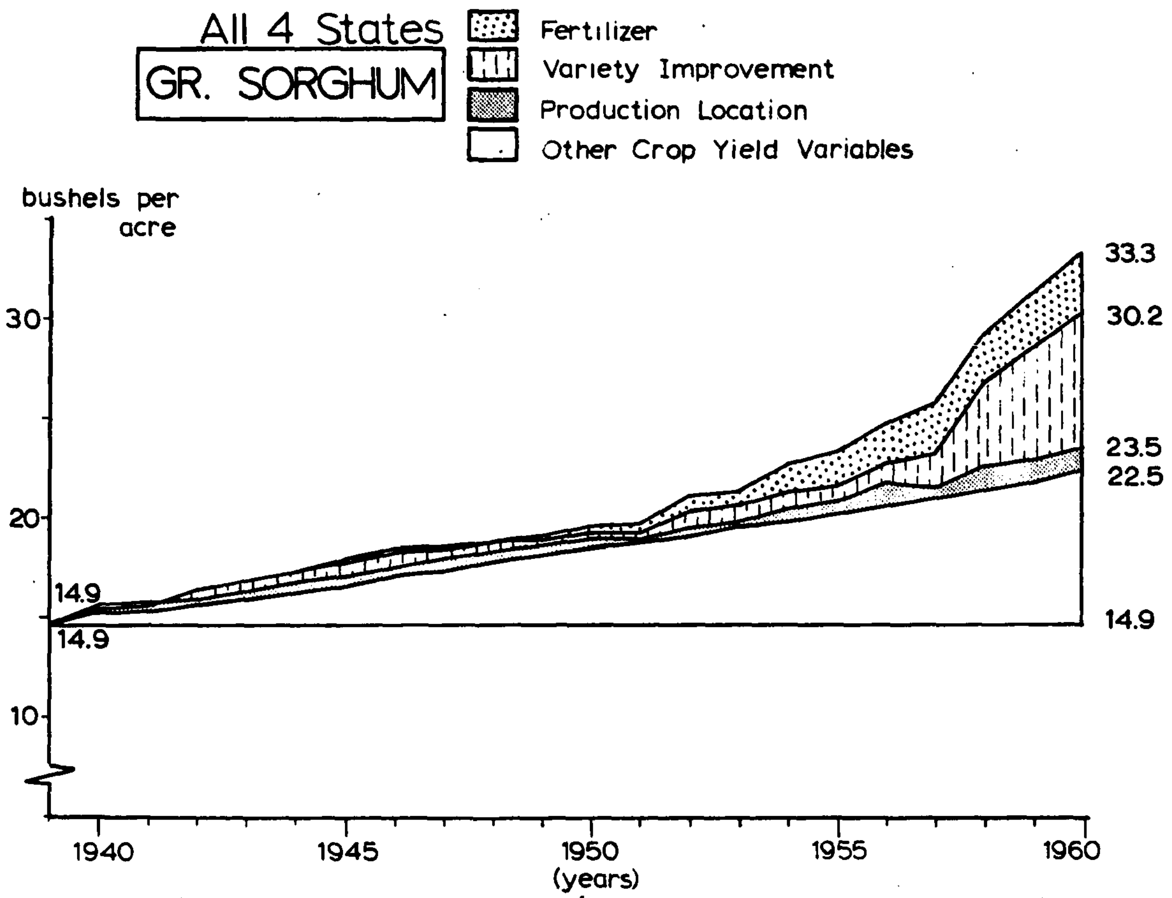

Figure 5.72. Aggregate grain sorghum yield changes, 1939 to 1960

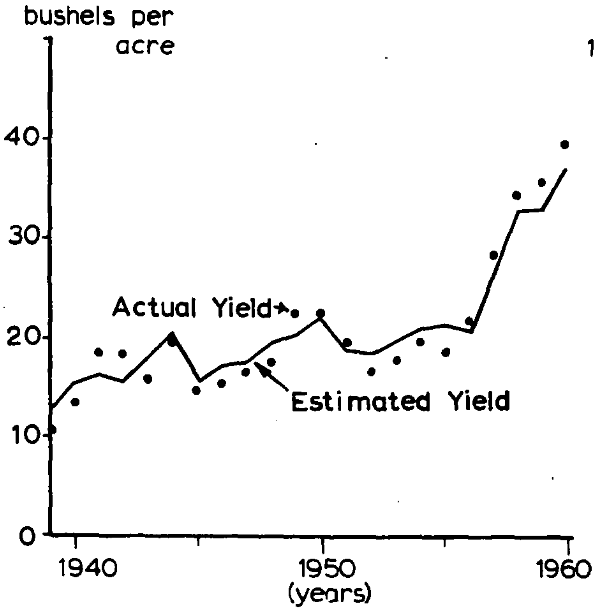

Figure 5.73. Yield comparisons

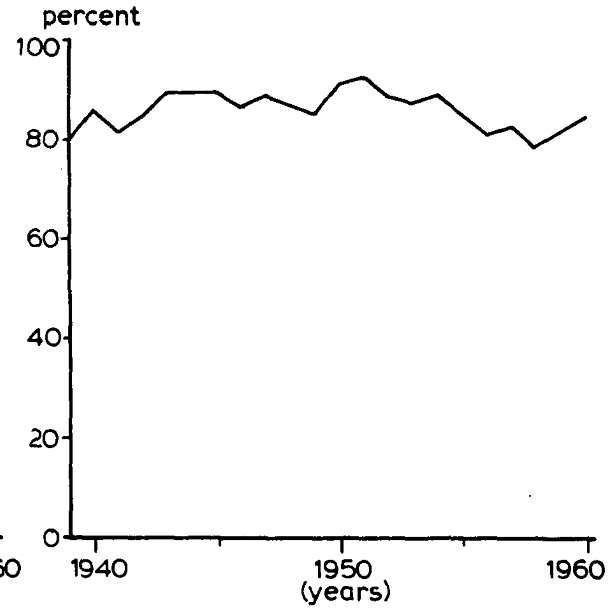

Figure 5.74. Percent of U.S. production

and contributed probably in large measure to yield increase as Texas lead all other states in grain sorghum production. Estimated and actual aggregate grain sorghum yields were highly correlated although there were periods of small but consistent under and overestimations which remained unexplained. Aggregate production of the four states included in the analysis accounted for 80 to 90 percent of U.S. production.

Corn Yields advanced strongly at almost constant rates from 30.0 bushels in 1939 to 55.8 bushels in 1961 by more than 85 percent (Figure 5.75). The analysis here covered over 80 percent of U.S. corn production in most years and therefore yield changes imputed to different technologies reflect what has happened to U.S. corn production over the last two decades. Of the 25.8 bushel yield change 8.1 bushels were attributed to higher rates of fertilizer application,[1] 9.2 bushels to adoption and improvement of hybrid corn, 4.6 bushels to regional specialization of corn production and the remainder of 3.9 bushels to other crop yield variables. Yield increase estimated for adoption and improvement of hybrid corn was large considering that more than one half of the Corn Belt acreage was planted with hybrid corn by 1939. Production location effects were positive over the whole time period and surpassed those of all other crops. Estimated production location effects measured the impact of regional specialization on aggregate corn yields. Long run acreage trends in low yielding Southern Plains and Delta States were negative, statistically highly significant and followed closely a straight line pattern in all states (Table 5.3). By contrast

[1]The yield change attributed to higher rates of fertilizer application follows from (55.8 bu. - 46.1 bu.) - (30.0 bu. - 28.4 bu.) = 8.1 bu.

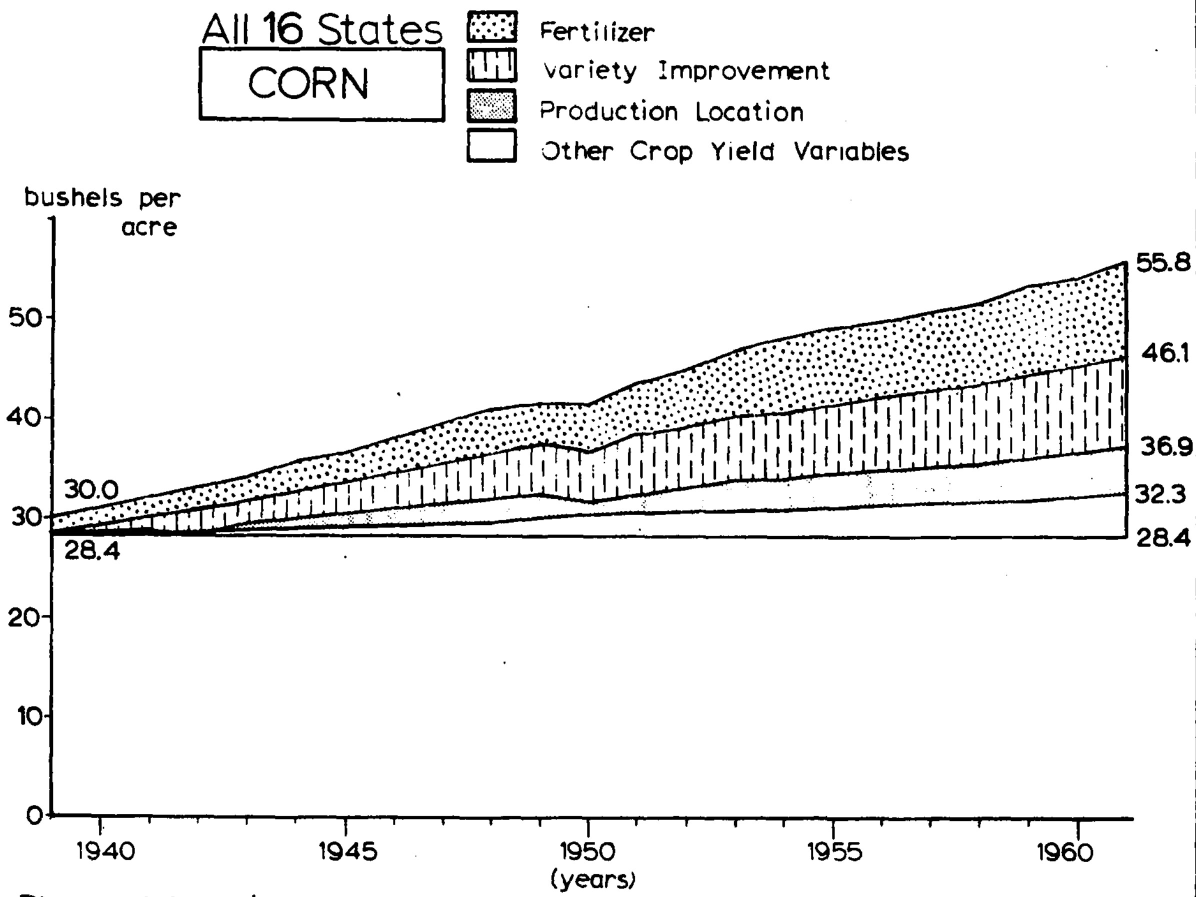

Figure 5.75. Aggregate corn yield change, 1939 to 1961

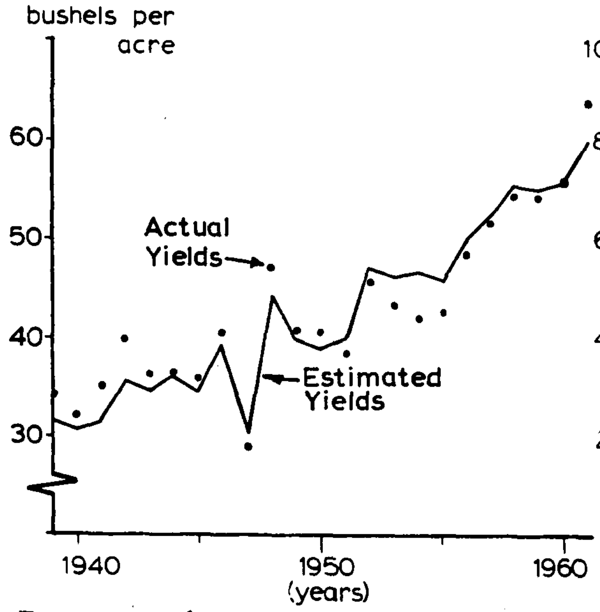

Figure 5.76. Yield comparisons

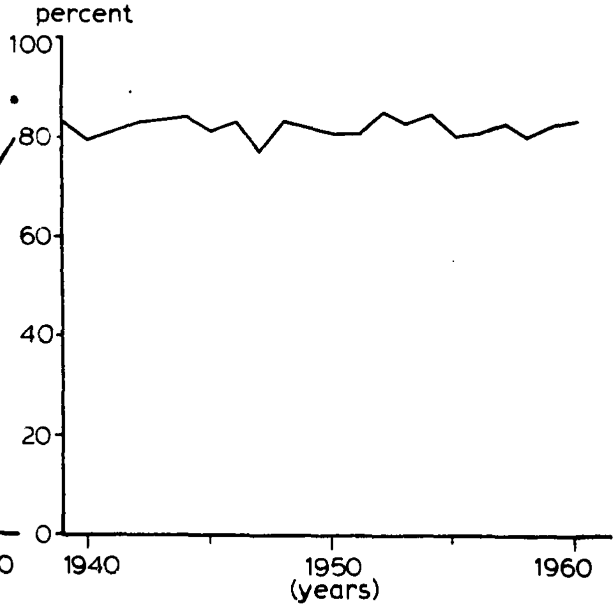

Figure 5.77. Percent of U.S. production

acreage trends of the more productive regions of the Corn Belt and Lake States were positively sloped, annual acreage change was more irregular and did not follow the same pattern in all states, but indicative of an overall expansion in acreage. Cumulative yield change advanced due to production location effects continuously with exception of the year 1950 when yield effects were negative as illustrated in Figure 5.75. This reduction was caused by a 3.4 million acre decline in Corn Belt acreage which coincided with a .8 million acre increase of low-yield corn acreage in Southern Plains and Delta States. Estimated and actual corn yields were highly correlated as evidenced by Figure 5.76 but estimated yields were slightly underestimated during the early forties and overestimated during the mid-fifties which might be indicative of auto-correlation among error residuals.[1] Estimates of production location effects were primarily dependent upon major yield differences between corn producing regions and only remotely related to error residuals between actual and estimated yields. Coefficients of state hybrid indices and plant nutrient response were based on *a priori* knowledge and could therefore not be biased by autocorrelated errors.

Tame hay Yields, relation between actual and estimated yields and annual percentages of U.S. hay production are illustrated by Figures 5.78 to 5.80. Most of the cumulative yield increase was ascribed to higher rates of fertilizer application and other unspecified yield variables. Production location effects were negative throughout but more pronounced

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[1]For measure of significance of autocorrelation of errors of estimate a statistical test, e.g. Durbin-Watson test, could be employed (50, p. 250).

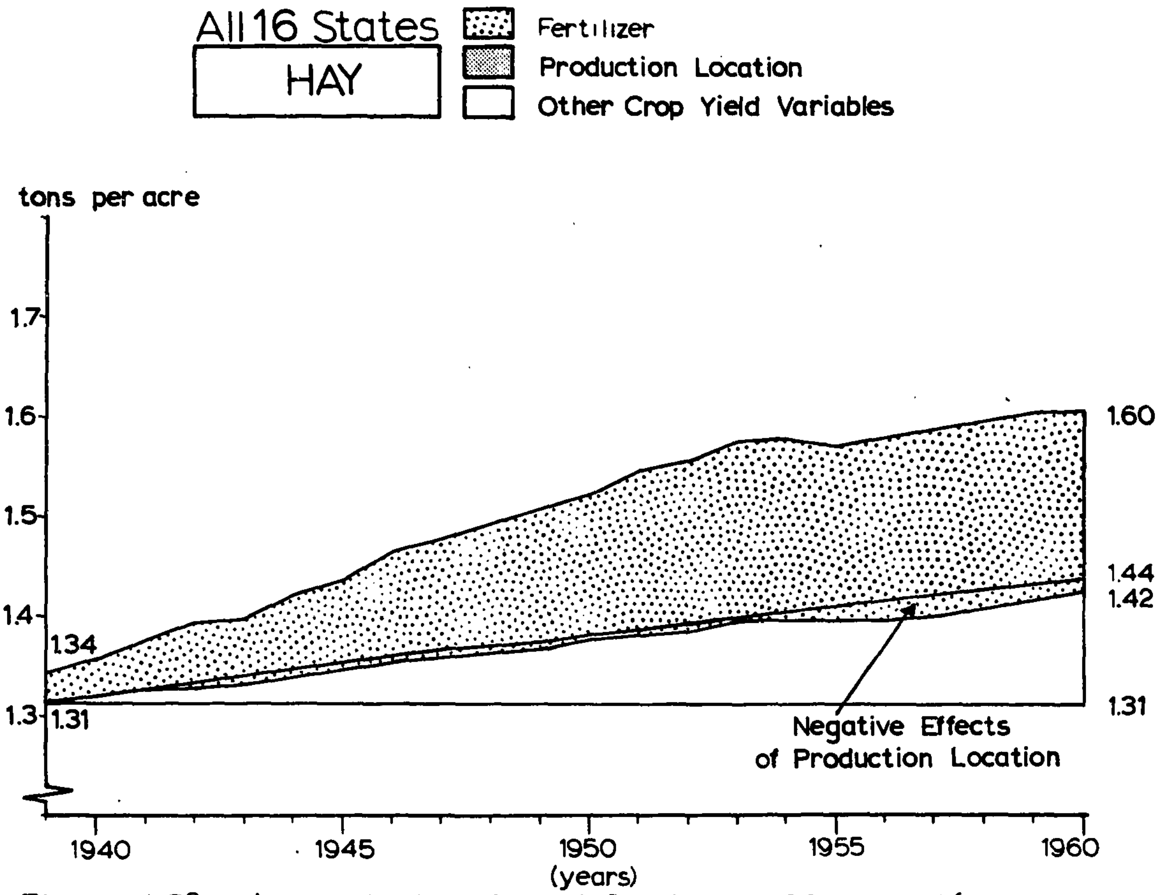

Figure 5.78. Aggregate tame hay yield change, 1939 to 1960

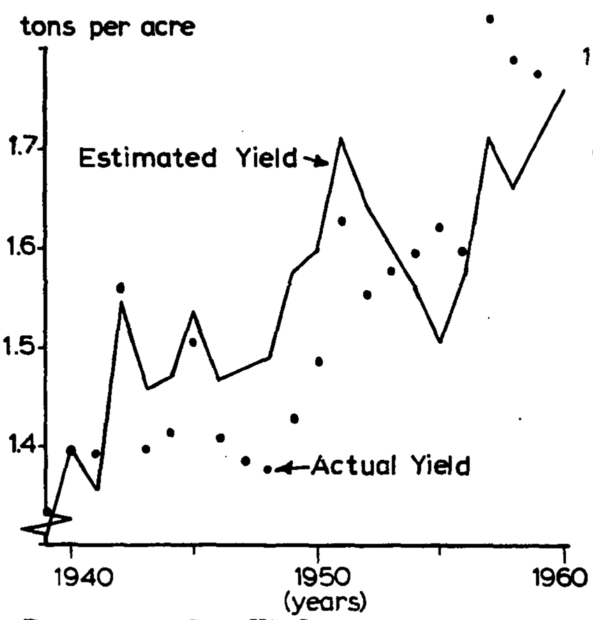

Figure 5.79. Yield comparisons

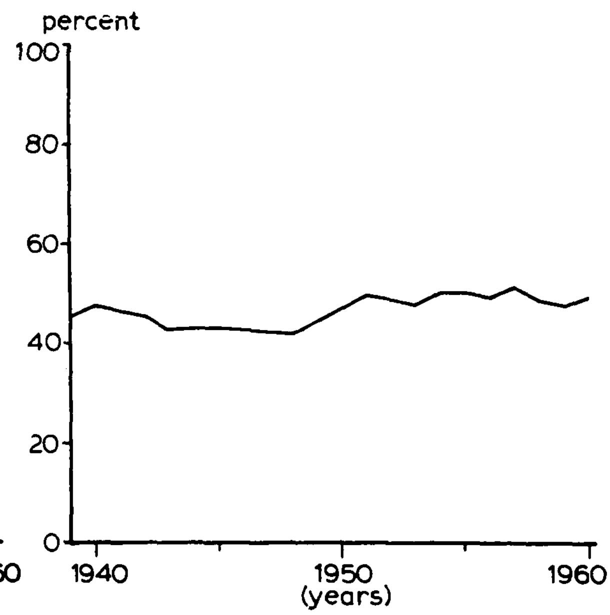

Figure 5.80. Percent of U.S. production

from 1950 to 1960 when tame hay acreage in lower yielding regions of the Northern Plains expanded while hay acreage in the Corn Belt and Lake States declined. Estimated yields followed the general pattern of actual yields but were not as highly correlated as those of other crops. Tame hay production analyzed in this study accounted from 40 to 50 percent of total U.S. hay production.

A summary of estimated increase in production and dollar value due to fertilization, crop variety improvement, production location and other crop yield variables is presented in Table 5.4. This summary includes all crops considered previously and refers to the yield increase of 1960 above base year values. In the first section of Table 5.4 estimated yield changes due to individual technologies are tabulated. For example, wheat yield changes per acre due to fertilization, variety improvement, production location and other wheat yield variables were estimated at 3.3, 2.1, .1, 2.1 bushels per acre respectively. These quantities are identical to cumulative yield changes shown in Figure 5.54 for all 13 wheat producing states in year 1960 and are equal to differences between 21.0, 17.7, 15.6, 15.5 and 13.4 bushels respectively where the yield of 13.4 bushels is the base year value defined as expected (aggregated) yield attained without fertilizer application. Corresponding quantities are listed for other crops in Table 5.4. Multiplying these yield changes by 1960 U.S. prices results in approximate dollar values added to gross return per acre attributable to different technologies. For example dollar value added to gross return per wheat acre due to fertilization is estimated at 5.78 dollars per acre. This is an approximate value since average U.S. price rather

Table 5.4. Aggregate change in crop yields and dollar value of production due to crop yield technology by crops in 1960

	Wheat	Oats	Soy-beans	Barley	Flax	Cotton	Grain Sorghum	Corn	Tame Hay
Base Year	1939	1942	1943	1943	1944	1939	1939	1939	1939
Yield change per acre[a] (in bu.) due to:									
Fertilization	3.3	3.1	1.3	1.4	.4	41.8	3.1	9.7	.18
Variety improvement	2.1	6.1	3.8	2.4	-.3	32.5	6.7	9.2	-
Production location	.1	.9	-1.4	.6	-.5	-3.8	1.0	4.6	-.02
Other crop yield variables	2.1	-5.6	.8	.1	-.1	104.7	7.6	3.9	.13
Total	7.6	4.5	4.5	4.5	-.5	175.2	18.4	27.4	.29
U.S. price in dollars/bu.[b]	1.750	.600	2.210	.837	2.660	.300	1.490	.998	21.700
Dollar value added to gross return per acre due to:									
Fertilization	5.78	1.86	2.87	1.17	1.06	12.54	4.62	9.68	3.91
Variety improvement	3.68	3.66	8.40	2.01	-.80	9.75	9.98	9.18	-
Production location	.18	.54	-3.09	.50	-1.33	-1.14	1.49	4.59	-.43
Other crop yield variables	3.68	-3.36	1.77	.08	-.27	31.41	11.32	3.89	2.82
Total	13.32	2.70	9.95	3.76	-1.34	52.56	27.41	27.34	6.30
Aggregate acres[c] in 1000:	36,818	22,786	19,562	5,071	3,140	9,795	13,675	65,130	30,584

[a]Refers to aggregate yield change of states included in analysis and in measured in bu. except for cotton and tame hay which is measured in pounds and tons respectively.

[b]Refers to 1960 prices per bu. except for cotton and hay where prices relate to pounds and tons respectively.

[c]Refers to 1960 (harvested) acreage aggregated over states included in analysis.

Table 5.4 (Continued)

	Wheat	Oats	Soy-beans	Barley	Flax	Cotton	Grain Sorghum	Corn	Tame Hay
Base Year	1939	1942	1943	1943	1944	1939	1939	1939	1939
Dollar value added to aggregate gross return (in million dollars) due to:									
Fertilization	212.8	42.4	56.1	5.9	3.3	122.8	63.2	630.5	119.6
Variety improvement	135.5	83.4	164.3	10.2	-2.5	95.5	136.5	597.9	-
Production location	6.6	12.3	-60.4	2.5	-4.2	-11.2	20.4	298.9	-13.2
Other crop yield variables	135.5	-76.6	34.6	.4	- .8	307.7	154.8	253.4	86.2
Total	409.4	61.5	194.6	19.0	-4.2	514.8	374.9	1780.7	192.6
Percent of U.S. production	70.4	86.0	83.3	32.1	89.3	51.4	84.8	83.6	48.3
	-	1.1628	1.2005	-	1.1198	-	1.1792	1.1962	-
Dollar value added to gross return of U.S. Agriculture (in million dollars) due to:									
Fertilization		49.3	67.3		3.7		74.5	754.2	
Variety inprovement		97.0	197.2		-2.8		161.0	715.2	
Production location		14.3	-72.5		-4.7		24.1	357.5	
Other crop yield variables		-89.1	41.5		- .9		182.5	303.1	
Total		71.5	233.5		-4.7		442.1	2130.0	

than an average state price weighted by relative state production was used. Dollar values added to aggregate gross return of states included in the analysis were found by multiplying per acre gross return by aggregate acres. Wheat acreage of selected states amounted to 36,818 million acres and dollar value added to gross return was estimated as 409.4 million dollars. Wheat production of 13 states included in this analysis averaged 70.4 percent of U.S. production in 1960 and between 60 to 70 percent over the last two decades (Figure 5.56). As impact of wheat yield technology on other wheat producing states might have differed considerable from those included here no estimates of dollar value added to gross return of U.S. Agriculture were made. If, however, production of selected states exceeded 80 percent of U.S. production of the crop in question estimates of dollar value added to gross return of U.S. Agriculture were made. They were estimated by multiplying estimates of selected state crops by adjustment factors to compensate for that portion of production not analyzed on state basis here. Estimates of dollar values added to U.S. Agriculture attributable to different technologies are shown in the last section of Table 5.4. Estimated total values ranged from (minus) 4.7 million dollars for flax to (plus) 2.13 billion dollars for corn. Grain sorghums and soybeans followed corn with 442.1 and 233.5 million dollars, trailed by oats with 71.5 million dollars. Among different crop yield technologies fertilization and variety improvement added most to gross value of production. In the case of corn a very substantial amount, estimated at 357.5 million dollars was added by positive production location effects of regional specialization. All dollar values cited here are estimates for the year

1960. Even greater additions to annual production can be expected in the future unless crop yield technology fails to advance.

Incentive to Greater Production

In the preceding discussion an account was given of the impact of crop yield technology on crop yields of states, regions, in aggregate and on U.S. production. Over the last two decades increased fertilizer use raised crop yields decisively. As more and more fertilizer is applied per acre of cropland its marginal physical productivity is bound to diminish unless shifts in crop production functions caused by newly adopted yield technologies more than compensate for declining marginal productivities. It will be shown next what stimulus economic incentives exerted in the past to induce greater fertilizer use and to what extent these incentives have been reduced, maintained or strengthened over the past two decades.

Analysis of the economics of production is patterned after the general framework presented in Chapter II. Economic incentive to greater production through yield increase is assumed to be a function of the ratio of annual expected yields Y_j over economic optimum yields $(Y_{opt})_j$ which is defined by 5.8. Algebraic derivation of economic optimum yields

$$Y_j/(Y_{opt})_j = b\, V_j\, T_j^t\, (N_j+1.0)^n\, (P_j+1.0)^p\, (K_j+1.0)^k/(Y_{opt})_j \tag{5.8}$$

$$\frac{\partial Y}{\partial N} = \frac{n\,Y}{N+1.0} = \frac{P_n}{P_y} \qquad N_{opt} = n\,Y\,\frac{P_y}{P_n} - 1.0 \tag{5.9}$$

$$\frac{\partial Y}{\partial P} = \frac{p\,Y}{P+1.0} = \frac{P_p}{P_y} \qquad P_{opt} = p\,Y\,\frac{P_y}{P_p} - 1.0 \tag{5.10}$$

$$\frac{oY}{oK} = \frac{k\,Y}{K+1.0} = \frac{P_k}{P_y} \qquad K_{opt} = k\,Y\,\frac{P_y}{P_k} - 1.0 \tag{5.11}$$

$$Y = b\,V\,T^t\,(n\,Y\,\frac{P_y}{P_n})^n\,(p\,Y\,\frac{P_y}{P_p})^p\,(k\,Y\,\frac{P_y}{P_k})^k \tag{5.12}$$

$$(Y_{opt})_j = \left[b\,V_j\,T_j^t\,(b\,V_j\,P_{yj})^{n+p+k}\,(\frac{n}{P_{nj}})^n\,(\frac{p}{P_{pj}})^p\,(\frac{k}{P_{kj}})^k\right]^{\frac{1}{1-n-p-k}} \tag{5.13}$$

is not affected by coding of fertilizer nutrient quantities. Conditions of economic optima of fertilizer use (in terms of N-P-K application rates per acre) are given in 5.9 to 5.11 where notations P_y, P_n, P_p, P_k represent crop and N, P and K prices. All other notations have been explained before in connection with formula 5.1. Equation 5.12 represents the crop yield supply function and is derived by inserting optimum nutrient quantities N_{opt}, P_{opt}, and K_{opt} in the general form of the production function. Evidently 5.12 is not affected by coding application rates as in 5.8.[1] Economic optimum yields Y_{opt} in 5.13 can be directly derived from 5.12 or simply by inserting appropriate coefficients in equation 2.17 (Chapter II) which defined optimum output given output price, n inputs and input prices. In equation 5.13 subscript j refers to the year for which optimum output $(Y_{opt})_j$ is computed on the basis of variety index V_j, (net) time trend variable T_j, crop price P_{yj} and N, P and K nutrient prices P_{nj}, P_{pj} and P_{kj} of the same year. No prices were attached to variety indices as price differentials between seed of older and newer varieties (or hybrids) are negligible or nonexistent and the price of other (unspecified) crop yield

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[1]However, statistical estimates of exponents and constant term b differ from those estimated on the basis of uncoded nutrient quantities.

variables was not known. Consequently ratio $Y_j/(Y_{opt})_j$ represents the ratio of expected over optimum yield attainable with optimum plant nutrient use given prices of crop and plant nutrients and given the level of all other crop yield technologies of anyone year.[1] Although the functional relationship between economic incentive and ratio of actual over economic optimum yield will not be formulated it may be readily assumed that the magnitude of the ratio is inversely related to the degree of incentive for greater production. If the ratio is small it pays to produce more, if it is large it does not.

The magnitude of ratio of expected over economic optimum yields depends, aside from annual values of crop yield variables, on prices. Crop prices have been published regularly by the U.S.D.A. whereas prices of plant nutrients have not and needed to be estimated. Prices of nitrogen were computed on the basis of single nutrient fertilizers ammonium nitrate, sulphate of ammonia and nitrate of soda in terms of price per pound of nitrogen. State data were available for the years 1950 to 1961 in most cases. To derive nitrogen prices by states, prices of each of the three types of nitrogen fertilizers were weighted according to relative state consumption. For earlier years prices of nitrogen of each of the three types of nitrogen fertilizers were derived on the basis of the 1950 state / U.S. price ratio and then weighted again according to relative state consumption. In a similar manner prices for phosphoric oxide and potash were estimated on state basis in price per pound of nutrient. Phosphoric oxide and potash

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[1]The term expected yield refers to estimated yield with annual acreage and weather indices fixed at unity as defined by equation 5.2.

prices were computed from state price data of superphosphate and muriate of potash respectively. State prices of earlier years were computed by using state/U.S. price ratios of later years. Differences between prices were for greater over time th~~an between~~ states and therefore errors introduced by estimating state prices from U.S. prices were not considered a serious impediment to meaningful economic analysis.

As indicators of economic incentive to greater production, ratios between expected and economic yields were computed for individual crops annually, by states and in aggregate. Time periods analyzed differed between crops as in previous sections and extended over the greater part of the last two decades in all cases. Annual yield ratios were expressed in percent and are plotted by individual states for each crop in Figures 5.81 to 5.99. Results of this analysis are discussed by crops in order followed previously.

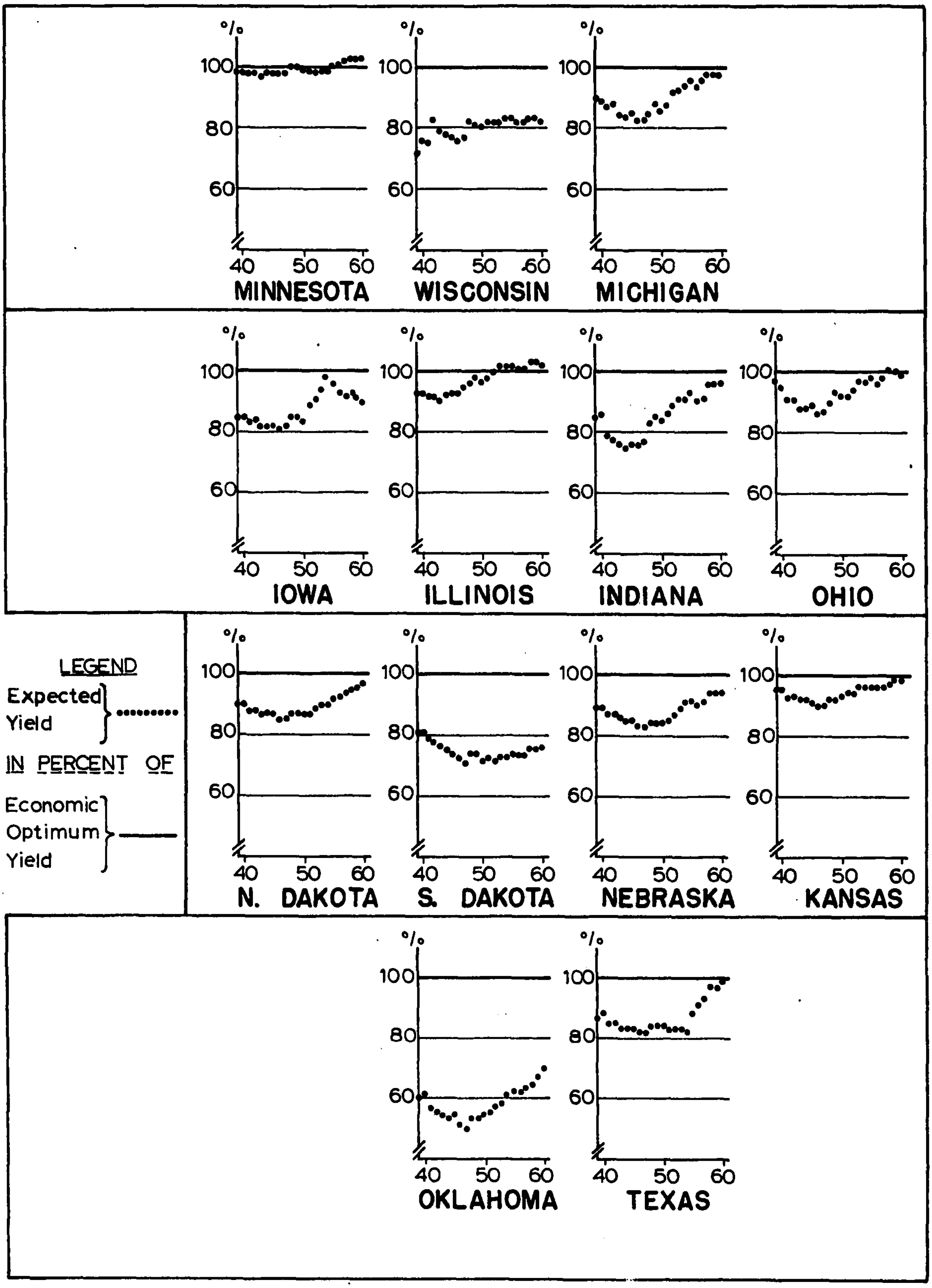
Wheat Yield ratios of expected yields in percent of economic optimum yields follow a somewhat similar pattern over time. According Figures 5.81 to 5.84 expected yields tended to decline relative to optimum yields during the early forties and then advanced quite rapidly towards economic optimum yields during the late fifties. In 1939, the first year of the analysis, expected state yields were below optimum yields in all 13 wheat producing states even if by only a small percentage as in Minnesota, Ohio and Kansas. Percentage ratios of most states reached minimum values shortly after 1945 and then progressed at differing rates towards economic optimum yields. Differences in rates of advance appeared to be inversely related to percentage differences between expected and economic optimum

Figure 5.81. Expected wheat yields in percent of economic optimum yields, Lake States, 1939 to 1960

Figure 5.82. Expected wheat yields in percent of economic optimum yields, Corn Belt States (excl. Missouri), 1939 to 1960

Figure 5.83. Expected wheat yields in percent of economic optimum yields, Northern Plains States (Spring wheat: N. Dak., S. Dak. Winter wheat: Nebr., Kans.), 1939 to 1960

Figure 5.84. Expected wheat yields in percent of economic optimum yields, Southern Plains States, 1939 to 1960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Economic Optimum Yield
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S. DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS

yields, a relationship which was more pronounced in some instances than others. Where this inverse relationship existed it implied that inducement to raise yield was strongest when the gap between expected and optimum yields was greatest. Changes in expected wheat yields of Wisconsin, South Dakota and Oklahoma appeared to be notable exceptions. In Wisconsin wheat was a minor crop, it occupied less than two percent of total cropland acreage over the past 20 years. The large discrepancy between expected and optimum wheat yields in Wisconsin which persisted over time does not necessarily imply misallocation of resources since farmers usually operate under resource restrictions and may have restricted output optima of different enterprises to varying degrees. As was pointed out earlier in Chapter II restricted output optima of different enterprises may differ relative to unrestricted output optima at varying degrees. Wheat production in South Dakota and Oklahoma has been characterized by extreme yield fluctuations. Risk aversion and capital rationing (51, pp. 550-555) might have prevented farmers in these drought areas from spending additional funds on more intensive fertilizer use. In Iowa expected wheat yields declined in recent years after they came close to economic optimum yields in the early fifties. This decline corresponded to reduction in fertilizer use since 1954. Estimates for other states followed a general pattern of decline in relative yields during the earlier period and a pronounced rise since 1947. This pattern was caused by increased fertilizer use as well as changes in price level. Since 1939 aggregate N-P-K application rates to wheat increased from 3.1 pounds to 22.3 pounds in 1960. The price index of food grains rose from 84 in 1940 to 271 in 1947 and then declined to 203 in 1960 (52, p. 7).

Oats Percentage ratios of expected oat yields over economic optimum yields are shown in Figures 5.85 to 5.88. The overall pattern of movement is not as uniform as in the case of wheat but some similarities between state patterns are discernible. Expected yields were below optimum yields during earlier years and approached but sometimes exceeded economic optimum yields in later years. Again expected yields of South Dakota moved towards optimum yields at a very slow pace. By contrast Oklahoma yields advanced rapidly but did not reach economic optimum yields in 1960. Expected oats yields of four out of 14 states, i.e. Michigan, Ohio, Indiana and Kansas, exceeded economic optimum yields by a considerable margin. In Minnesota, Iowa and especially Illinois expected yields dropped due to significant reductions in nutrient application. Oats acreages declined sharply in these states during recent years but this decline did not appear to be more pronounced than in other states and could not serve as sufficient explanation for reduction in fertilizer application rates.

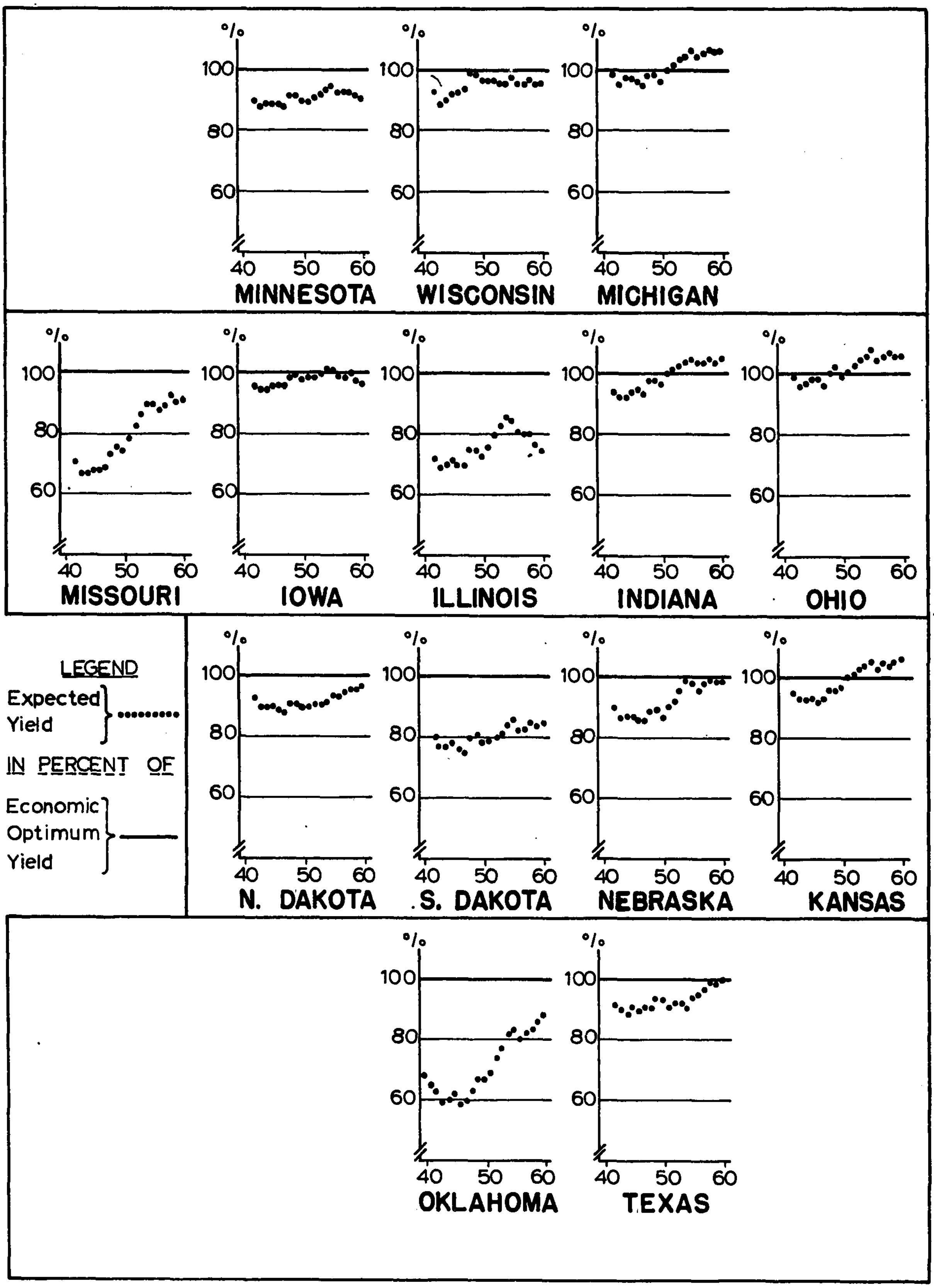
Soybeans A glance at Figures 5.89 to 5.91 conveys the impression that percentage yield ratios of soybeans were close to optimum in most states over most of the time period. In this case close correspondence between expected and optimum yields can be largely attributed to low fertilizer response of soybeans. As a result of low response to fertilizer application expected soybean yields could not differ greatly from optimum yields in most of the states. Apparent exceptions were yield ratios of Wisconsin, Illinois, Ohio and Arkansas. In all three states soybean yield response to fertilizer was greater than average regional response and expected yields approached economic optimum yields more closely in 1960 than in earlier years.

Figure 5.85. Expected oat yields in percent of economic optimum yields, Lake States, 1942 to 1960

Figure 5.86. Expected oat yields in percent of economic optimum yields, Corn Belt States, 1942 to 1960

Figure 5.87. Expected oat yields in percent of economic optimum yields, Northern Plains States, 1942 to 1960

Figure 5.88. Expected oat yields in percent of economic optimum yields, Southern Plains States, 1942 to 1960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S. DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
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100
80
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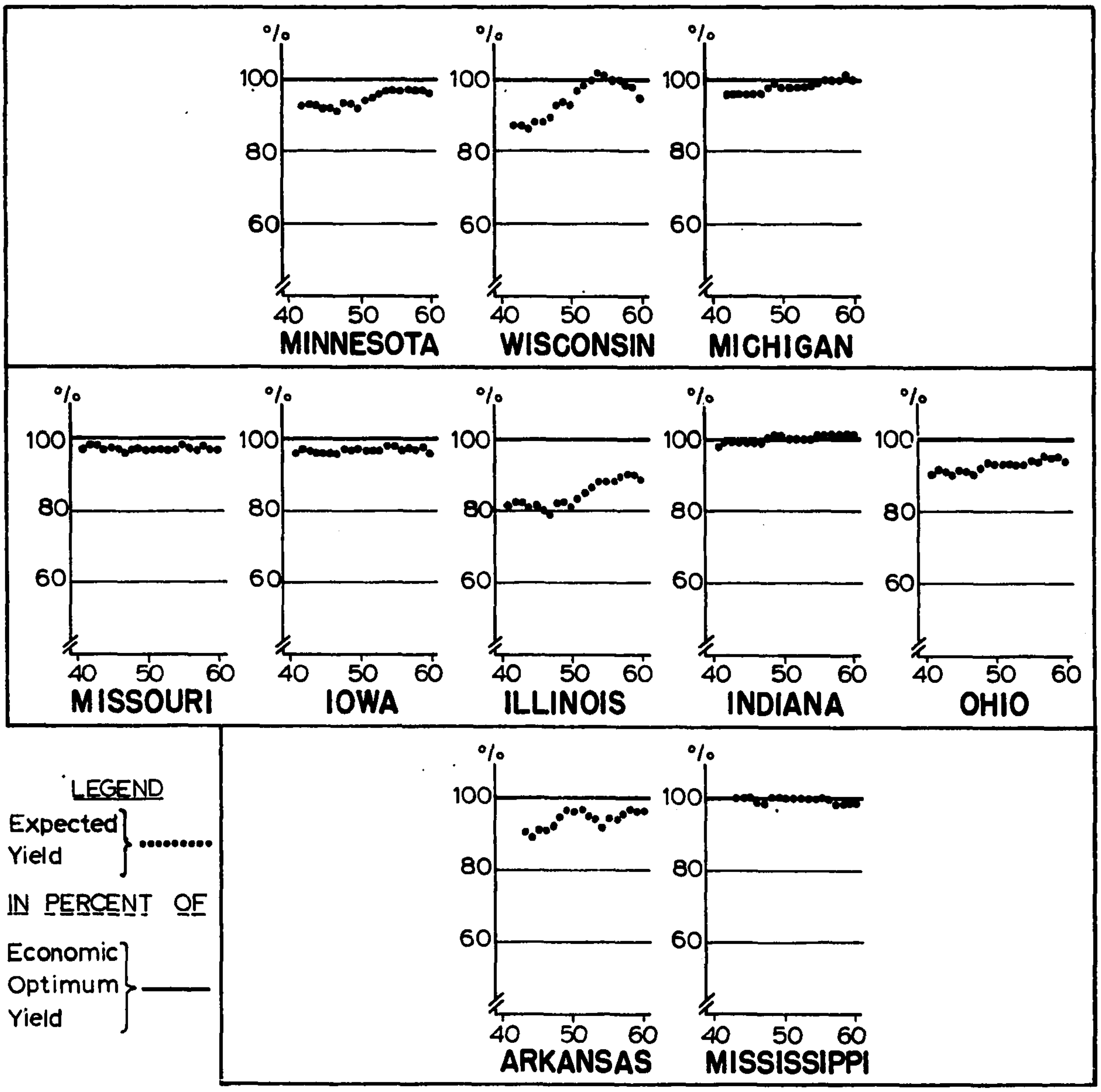
60

Figure 5.89. Expected soybean yields, in percent of economic optimum yields, Lake States, 1942 to 1960

Figure 5.90. Expected soybean yields in percent of economic optimum yields, Corn Belt States, 1941 to 1960

Figure 5.91. Expected soybean yields in percent of economic optimum yields, Delta States (excl. Louisiana), 1943 to 1960



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LEGEND
Expected Yield
IN PERCENT OF
Economic Optimum Yield

Barley, flax, cotton, grain sorghum Expected barley yields of Minnesota, North Dakota and Nebraska came very close to economic optimum yields but South Dakota barley yields did not (Figure 5.92). This discrepancy between expected and optimum barley yields in South Dakota corresponds to similar differences in wheat and oats yields, and is even more pronounced with respect to flax yields (Figure 5.93). Percentage ratios of expected over optimum flax yield were highest for Minnesota and lowest for South Dakota where expected flax yields were over 40 percent below economic optimum yields. Again risk aversion may have induced farmers to refrain from higher fertilizer application as year to year variations in flax yields were unusually large (Figure 5.67). - Cotton yields nearly coincided with economic optimum yields in three out of four states and were only five percent below optimum in Oklahoma by 1960 (Figure 5.94). This close correspondence between expected and economic optimum yields of cotton is remarkable as cotton is highly responsive to fertilizer and fertilizer application rates have increased from 6.8 pounds in 1939 to 57.1 pounds in 1960 over the four state area which produced about one half of the total U.S. cotton (Figure 5.71). Similarly expected yields of grain sorghum approached economic optimum yields towards the end of the last decade (Figure 5.95).

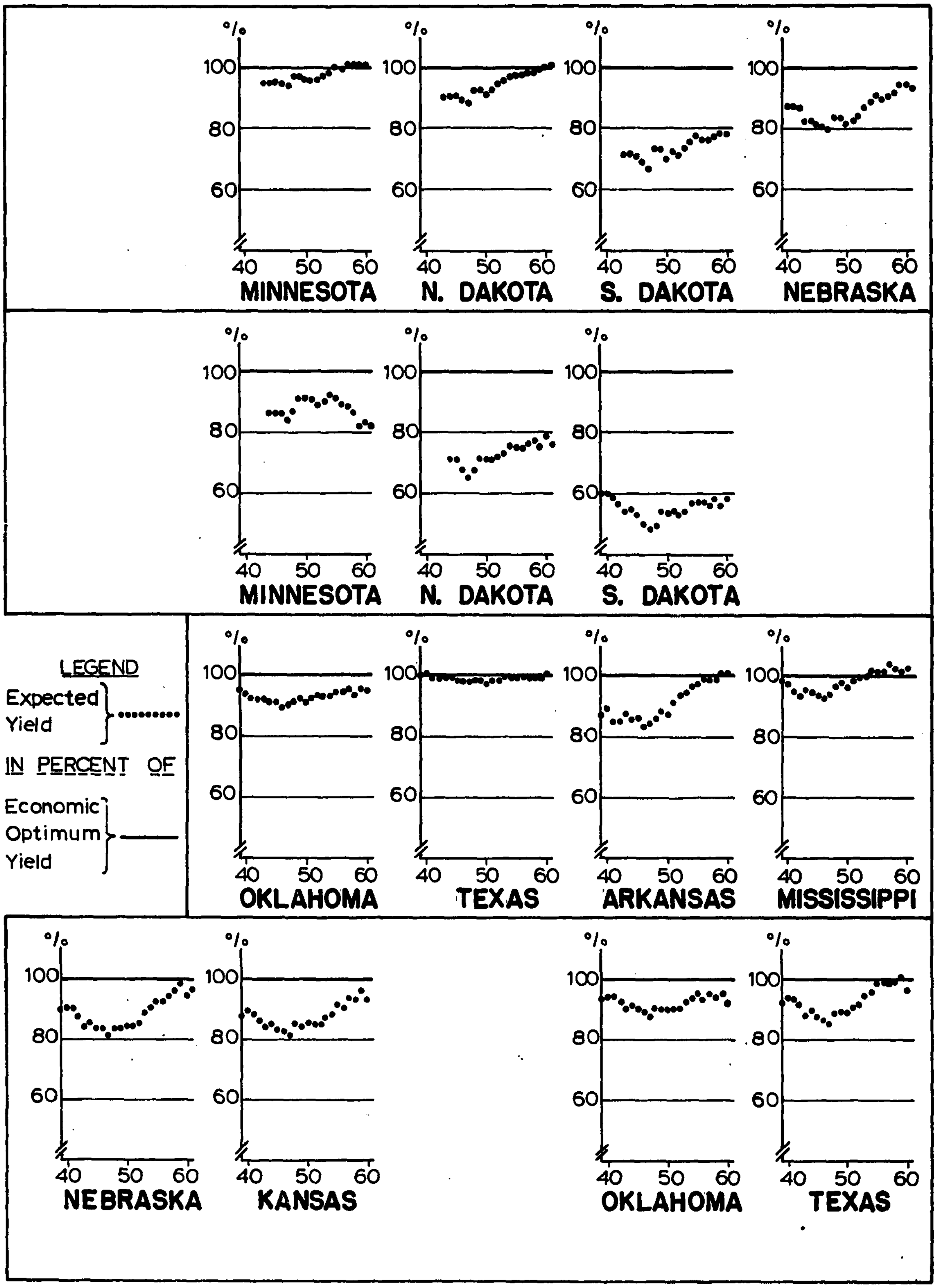
Corn Comparison between expected and optimum yields of corn reveals surprising uniformity among 16 states included in the analysis. During the early years percentage yield ratios declined, reached a low in 1947 and then advanced towards economic optimum yields in all states without exception (Figure 5.96 to 5.99). A partial explanation of this pattern is

Figure 5.92. Expected barley yields in percent of economic optimum yields, Minnesota and Northern Plains States (excl. Kansas), 1943 to 1960

Figure 5.93. Expected flax yields in percent of economic optimum yields, Minnesota, North and South Dakota, 1944 to 1960

Figure 5.94. Expected cotton yields in percent of economic optimum yields, Southern Plains and Delta States (excl. Louisiana), 1939 to 1960

Figure 5.95. Expected grain sorghum yields in percent of economic optimum yields, Northern Plains (excl. North and South Dakota) and Southern Plains States, 1939 to 1960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MINNESOTA
N. DAKOTA
S. DAKOTA
LEGEND
Expected Yield
IN PERCENT OF
Economic Optimum Yield
OKLAHOMA
TEXAS
ARKANSAS
MISSISSIPPI
NEBRASKA
KANSAS
OKLAHOMA
TEXAS

given by concurrent but inversely related changes in feed grain prices which in terms of index numbers[1] rose from approximately 85 in 1940 to 258 in 1948 and then declined to 151 in 1960 (52, p. 7). Much of the change in the yield ratio, however, must be attributed to higher rates of fertilizer application which increased in aggregate from 3.1 pounds in 1939 to 71.8 pounds in 1961. Expected corn yields exceeded estimated optimum yields in 11 out of 16 corn producing states in 1961, a striking likeness of estimated ratios among corn producing states. According to this analysis fertilizer application rates to corn in 1961 were about 10 pounds below estimated optimum application rates[2] of 1947 when corn prices exceeded two dollars per bushels. In 1961 corn prices were close to one dollar per bushel, a reduction in price which might be expected to discourage rather than stimulate greater fertilizer use. However it must be remembered that expected yields and optimum yields were computed with reference to normal weather conditions. In 1947 weather conditions were far below normal and a poor corn crop raised corn price above normal (See Appendix Table D.2). Conversely during recent years weather conditions were above normal and excess corn production depressed market prices. A rise in corn price increases economic optimum fertilizer use more than proportionately since the crosselasticity of corn price for fertilizer is greater than unity which follows from formula 2.16 in Chapter II. If corn prices of

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[1]Index numbers approximate changes in feed grain prices as they refer to both feed grains and hay.

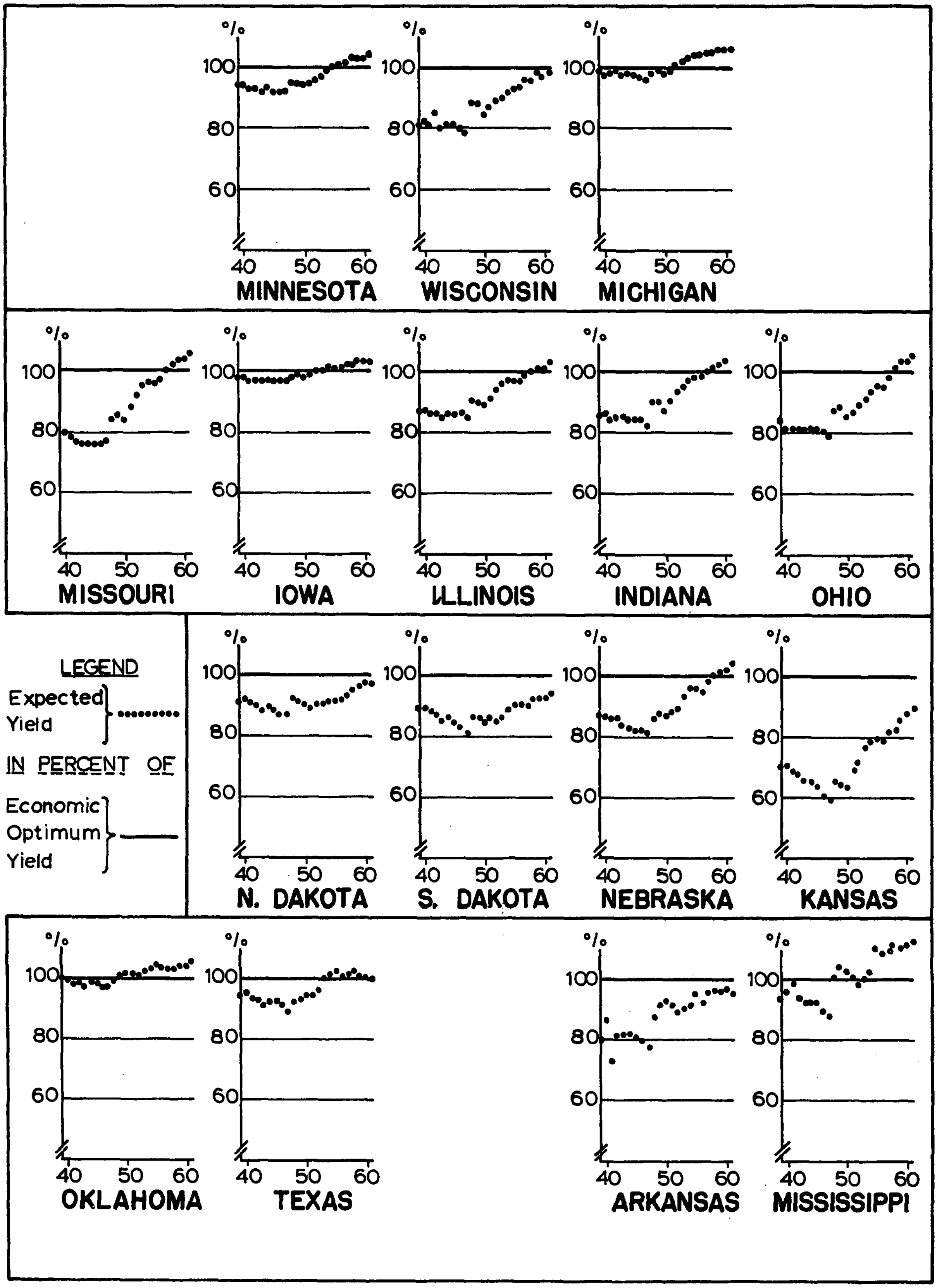
[2]Average optimum application rates of 16 states weighted by relative state acres.

Figure 5.96. Expected corn yields in percent of economic optimum yields, Lake States, 1939 to 1961

Figure 5.97. Expected corn yields in percent of economic optimum yields, Corn Belt States, 1939 to 1961

Figure 5.98. Expected corn yields in percent of economic optimum yields, Northern Plains States, 1939 to 1961

Figure 5.99. Expected corn yields in percent of economic optimum yields, Southern Plains and Delta States (excl. Louisiana), 1939 to 1961


%
100
80
60
40 50 60
MINNESOTA
WISCONSIN
MICHIGAN
MISSOURI
IOWA
ILLINOIS
INDIANA
OHIO
LEGEND
Expected Yield
IN PERCENT OF
Economic Optimum Yield
N. DAKOTA
S. DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
ARKANSAS
MISSISSIPPI

recent years had been closer to long run average, economic optimum yields would be higher and consequently ratios between expected and optimum yields lower than indicated by Figures 5.96 to 5.99. In as far as above average weather conditions shifted corn production functions upward farmers were justified in applying greater amounts of fertilizer than could be recommended (as optimal from an economic point of view) under normal weather conditions.

It was the objective of the preceding analysis to determine if economic incentives to greater production had been reduced, maintained or strengthened over the past two decades. According to results of this analysis the economic incentive to greater production by more intensive fertilizer use has been reduced greatly with regard to all major crops in most states. Aggregate results of this analysis are presented in Figures 5.100 to 5.107 where aggregate expected yields are compared to economic optimum yields. With the exception of flax yields differences between expected and economic optimum yields have been greatly reduced over the last two decades. If it is assumed that profitability induced farmers to increase crop yields in the past then it follows that attainment of yield increase in the future will not be comparable to that of the past. This statement implies that economic incentives to produce more per acre have gradually diminished, it does not imply that crop yields will fail to advance in the future. They may continue to increase at rates comparable to those of the past but to do so will require changes in the incentive structure.

In order to predict future crop yields expected price changes and progress in technology need to be taken into account. Higher crop prices

Expected Yield in Percent of Economic Optimum Yield

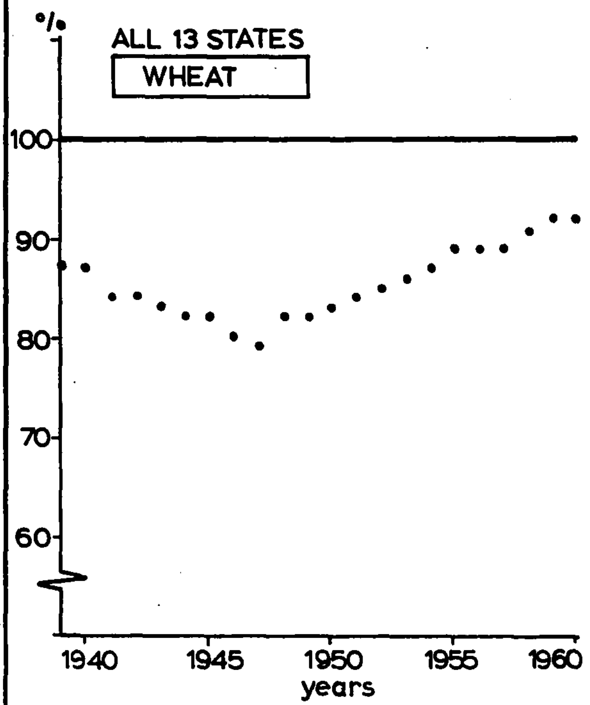


Figure 5.100. Wheat yields in percent of optimum yields, 1939-60

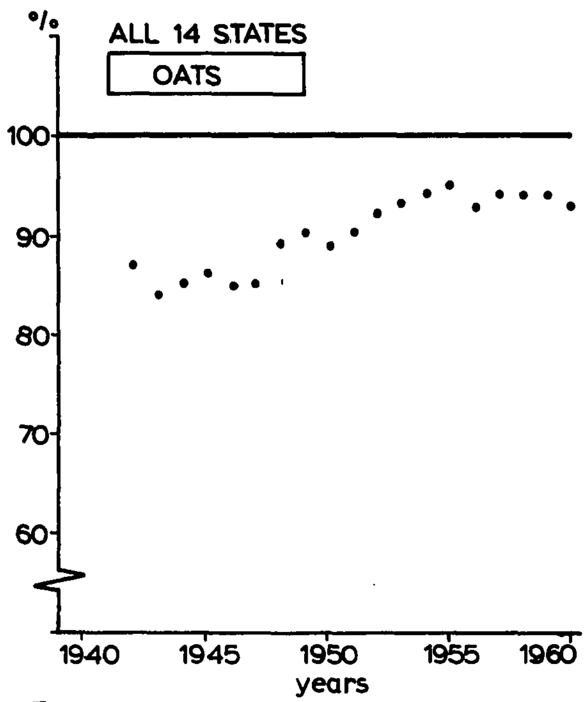


Figure 5.101. Oat yields in percent of optimum yields, 1942-60

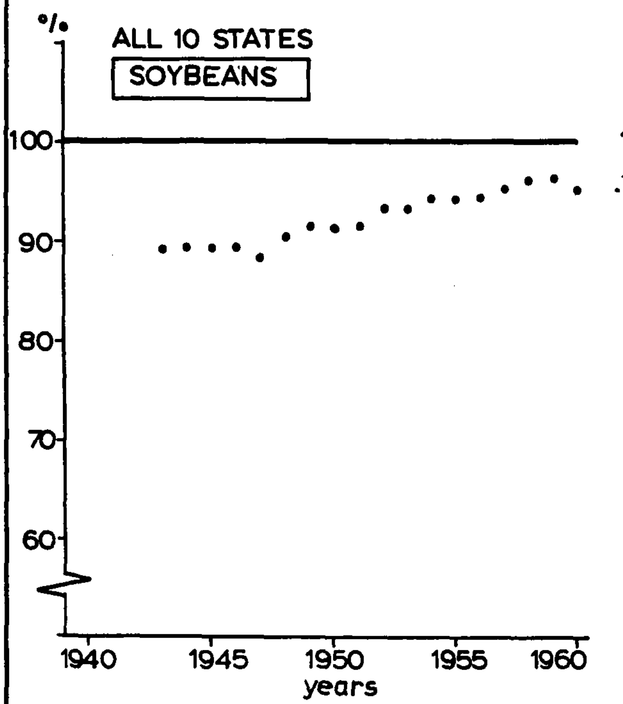


Figure 5.102. Soybean yields in percent of optimum yields, 1943-60

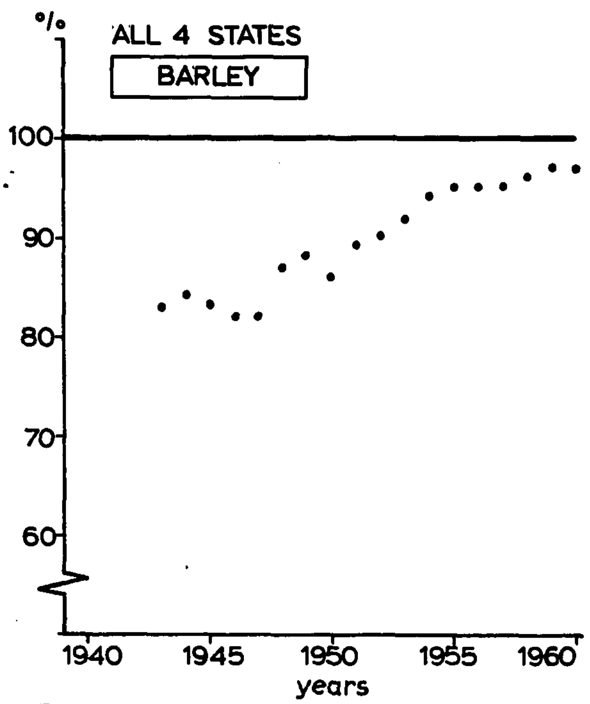


Figure 5.103. Barley yields in percent of optimum yields, 1943-60

Expected Yield in Percent of Economic Optimum Yield

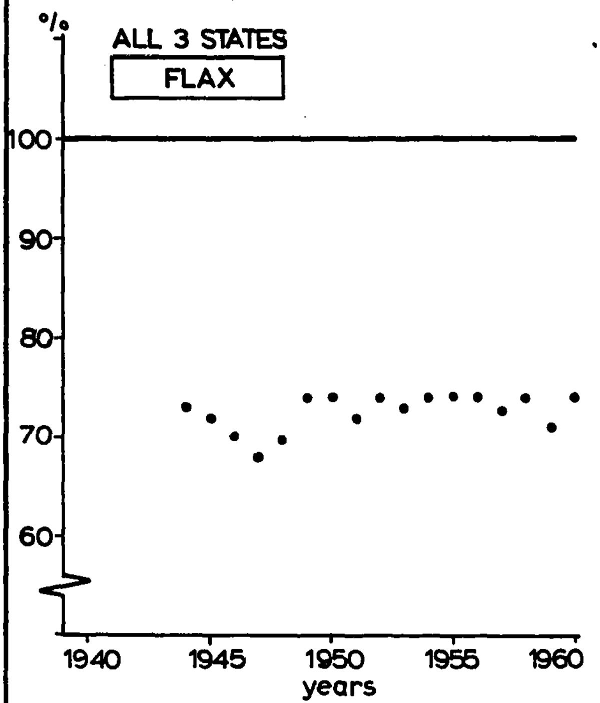


Figure 5.104. Flax yields in percent of optimum yields, 1944-60

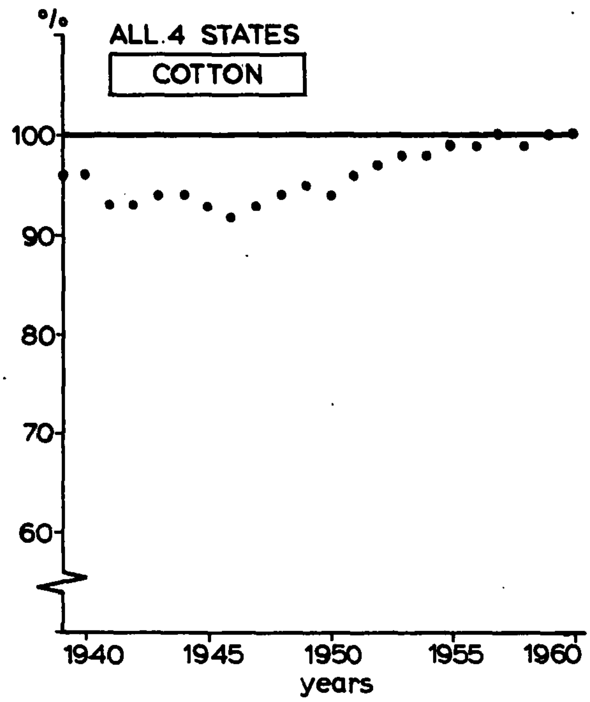


Figure 5.105. Cotton yields in percent of optimum yields, 1939-60

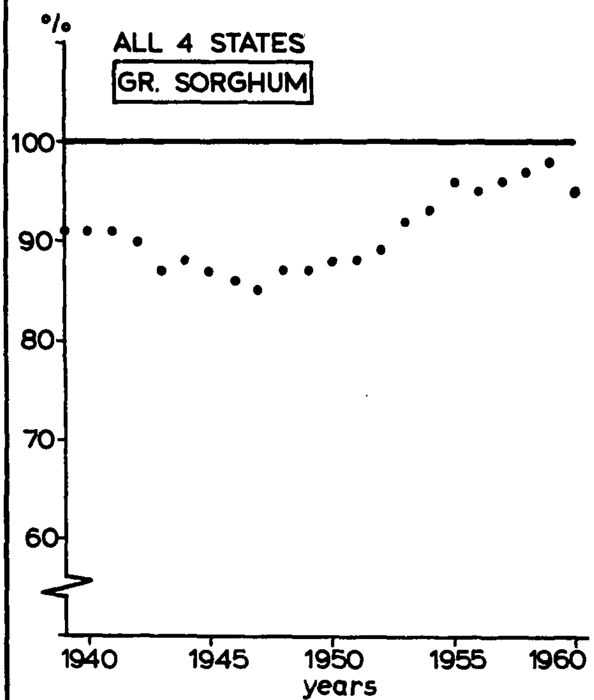


Figure 5.106. Sorghum yields in percent of optimum yields, 1939-60

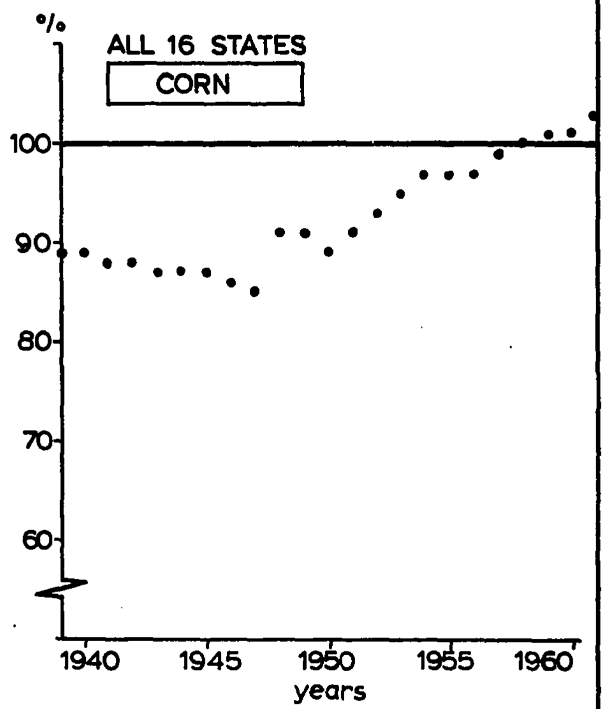


Figure 5.107. Corn yields in percent of optimum yields, 1939-61

and lower fertilizer prices will likely induce farmers to produce more per acre. With a rise in crop prices economic optimum yields, as defined earlier, will increase less than proportionately and fertilizer demand more than proportionately. With a reduction of fertilizer prices quantities demanded will increase more than proportionately and optimum yields less than proportionately. These input-output price quantity relationships follow directly from elasticities of supply and demand defined in Chapter II. Aside from future price changes economic optimum yields will depend on future technology. New technology, like introduction, adoption and continuous improvement of hybrid corn, raises crop yields. At the same time it increases demand for other yield increasing inputs. For example, if adoption and further improvement of hybrid corn had been halted in 1939 economic optimum rates of fertilizer application in 1961 would have been 24 percent lower. As a result annual optimum corn yields of 16 corn producing states (accounting for more than 80 percent of U.S. corn production) would have been reduced by an estimated 22 percent, a prime example of mutual dependence between private enterprise and government sponsored research. - Projections of past yield trends may not be appropriate to predict future developments of crop yield technology. For example, adoption of grain sorghum hybrids has greatly contributed to yield increase over the past few years (Figure 5.72) but can not be expected to contribute nearly as much in the next five years because over 80 percent of the total grain sorghum acreage is planted to hybrids already. What crop yield changes, attributable to variety and hybridization, can be expected in the future needs to be estimated on the basis of information of the past (as presented here) and expectations of research workers in the field of crop variety improvement. Also future trends of other crop yield variables, e.g. irrigation, need to be projected. Once these variables have been quantified projections of future production can be made under various price assumptions.

Future crop yields will not be the sole determinant of future crop production. Crop production is the product of crop yield and acreage. As was pointed out in Chapter I total crop acreage has declined over the past twenty years. Whether or not it will pay to use more land in order to meet future needs will depend on substitution rates and price ratios between land and other factor inputs at future levels of crop yield technology. Assuming crop yield production functions can be predicted, future rates of substitution between land and other inputs can be estimated. For estimation of these quantities production function analysis can be usefully employed (53). State crop production functions presented earlier can be simplified by combining N-P-K application rates into a given mix. For example in production function 5.14 F/A refers to application rate of nutrient mix per acre.[1] The marginal rate of substitution of fertilizer for

[1]Nutrient application rates in state crop production functions, presented earlier were coded. Conversion of these to nutrient mix functions is shown below:

$$Y = b_o \, V \, (N+1.0)^n \, (P+1.0)^p \, (K+1.0)^k \, T^t$$

$$F/A = N+P+K$$

$$r_n = (N+1.0) \; / \; (N+P+K+3.0)$$

$$r_p = (P+1.0) \; / \; (N+P+K+3.0)$$

$$r_k = (K+1.0) \; / \; (N+P+K+3.0)$$

$$Y = b_o \, V r_n^n \, r_p^p \, r_k^k \, (\tfrac{F}{A}+3)^{n+p+k} \, T^t$$

$$Y = b_o V (\frac{F}{A})^f T^t \tag{5.14}$$

$$\frac{\partial A}{\partial F} = - \frac{f}{1+f} (\frac{P_o}{b_o V F})^{\frac{1}{1-f}} (\frac{1}{T})^{\frac{t}{1-f}} \tag{5.15}$$

land derived from 5.14 is 5.15 where A refers to acres, F is total nutrient use, f is the exponent of nutrient application, P_o is a given level of crop production, b_o is a constant term, V is variety index, T is an index, of other crop yield variables and t is its coefficient. According to 5.15 the marginal rate of substitution of fertilizer (nutrient mix) is negative as f is assumed to be smaller than unity. As nutrient use F increases and/or crop variety improvement V and/or other crop yield technology advances the absolute value of oA/oF declines. This implies that it will require more and more fertilizer to compensate for additional reductions in crop acreage. However, as new crop yield technology is adopted need for greater acreage is lessened. How much cropland, what quantities of fertilizer, how much research inputs will be required to meet future demand will depend on input-output price relationships which in turn depend on macro-demand and supply variables. In this study impact of crop yield technology was analyzed by application of microeconomic theory, it would be useful to incorporate results of this study in macroeconomic analysis.

CHAPTER VI

LIMITATIONS, SUMMARY AND CONCLUSION

Errors of crop yield variates affected production function estimates. Changes in state crop yields attributable to crop variety improvement and fertilizer response were incorporated in the production function analysis on the basis of a priori knowledge. Estimated crop variety indices were subject to error. Results of ca. 28,000 crop variety yield tests and over 60,000 corn hybrid tests were used for index computations. Test yield comparisons were aggregated over state areas and sometimes over states. In aggregating yield comparisons acreage weights were used for relative corn hybrid yields but not for relative yields of other crop varieties. Acreage weights may not have been good measure of regional corn production. Crop variety - location interactions may have been ignored, yield increase attributed to recently introduced varieties might have under or over estimated true response as available test results may have been insufficient in number. Inaccuracies of yield comparisons may have resulted if variance of relative test yields was caused by instability of yields of check varieties. Usually estimates of relative acreage planted to individual crop varieties were not based on sample surveys but obtained from research workers engaged in research pertaining to state crop variety improvement. It remained unknown how seriously inaccuracies of crop variety indices affected production function estimates but could be determined by more detailed analysis.

Estimates of fertilizer use were derived from results of six nationwide surveys of fertilizer practices. Adjustments were made for comparability of survey results. Application rates of intervening years were estimated by interpolation but restricted by total state consumption. In exceptional cases results were questionable. For example, nutrient application rates to hay in Kansas, Southern Plains and Delta States were relatively high in 1950, Illinois application rates to hay were high in 1954 and declined thereafter (Appendix Tables C). These changes in rates were not considered realistic and contributed in part to excluding hay from more detailed economic analysis. Overestimation of fertilizer application to (tame) hay could have seriously affected estimates of rates of other crops if it had made up the greater portion of total consumption.

Fertilizer response coefficients were estimated independently from coefficients of other crop yield variables. They were estimated by states, crops and nutrients on the basis of published U.S.D.A. data (45) and related to crop yield technology of the years 1947 to 1949 which formed the base year of crop variety and corn hybrid indices. The fact that plant nutrient response data were published on state basis was of advantage here. It permitted incorporation of results in the present study without further adjustments. However, what appeared to be advantageous for this study may not be so for more elaborate studies. If impact of crop yield technology is to be analyzed by state-areas rather than on state basis fertilizer response estimates of state-areas gain importance, particularly if crop production functions are to be related to detailed regional programming studies. Over time fertilizer response changes as other crop yield technology advances. Fertilizer response on irrigated land differs from dry land response. As more land is irrigated, fertilizer response may shift within and between state regions. There may be interactions between fertilizer and variety (hybrid) improvements. Different plant nutrients may change in relative importance. Corn yield response to nitrogen, for example, may have been underestimated a decade ago. It would be most useful if future analyses of fertilizer response could be more closely related to specified levels of crop yield technology of state regions provided estimates of nutrient application are made available at the same level of disaggregation.

Effects of other crop yield technologies were estimated here by including a net time trend variable in the production function analysis. As coefficients of crop variety improvement and fertilizer response were predetermined they could not be affected by statistical estimations of the net time trend coefficient. By contrast the net time trend coefficient served to estimate whatever yield trends remained after accounting for crop yield change caused by variety improvement and change in fertilizer use and was therefore dependent upon the magnitude of the predetermined coefficients. The net time trend variable was especially adapted to pick up unidentified but constant rates of yield change attributable to other crop yield variables, it was not suited to account for irregular and abrupt changes in unidentified technologies.

For estimation of weather effects on crop yields phenological weather indices were estimated by crops and states. Corn weather indices were based on deviations of annual corn test yields from trend line values, weather indices of other crops were estimated on the basis of yield deviations of individual varieties from their long run average yields. Inevitably these weather indices were confounded with effects of other variables such as crop disease, station-location and variety-disease interactions. For superior analysis it would be most desirable to quantify location-yield relationships, i.e. relate yield variations on experiment station plots to yield variations of surrounding regions, in appropriate manner. It would probably be useful to separate crop yield weather effects from crop yield disease effects not only for superior weather indices but also for better comparisons between yield potentials of individual varieties. Instead of a crop variety index and weather index as estimated here the production function would contain a crop variety index (excl. disease effects), a weather index (excl. disease effects) and a separate crop disease index accounting for yield variations attributable to varying degrees of disease intensity and variety susceptibility. Adequate estimation of weather effects is essential because inferior estimates may bias coefficients of net time trend variables and acreage indices.

Annual changes in crop acres were measured in terms of relative deviations from trend acres. As acreage of a crop is expanded yield reduction may be expected as not all land is equally suited for production of a particular crop. Acreage indices which measured relative deviation from trend acres were usually negative for soybeans, hay and for crops grown in northern regions but irregular for other crops and regions. If farmers find it profitable to expand acreage of a particular crop because of price increase, it pays to increase fertilizer applications to that crop. To the extent that short run changes in application rates to individual crops were underestimated acreage effects may have been confounded with fertilizer effects. It is unlikely that these estimates can be improved unless surveys on fertilizer use are conducted annually or the farmer's response to crop price changes in terms of distribution of fertilizer among competing crops becomes better known. It is also quite possible that acreage indices were confounded with weather variations as acreage deviations were derived from estimates of harvested rather than planted acreage. Acreage abandonment is more likely to occur during a crop year of bad weather conditions. Consequently acreage and weather indices may move together. Although correlation between both indices was generally insignificant some estimates of acreage coefficients might have been adversely affected. In addition, acreage estimates were subject to error. For example, estimates of Kansas tame hay acreage as defined in this study, proved to be inaccurate. Kansas production function estimates of tame hay were rejected because underestimation of tame hay acreage appeared to be the cause of unreasonable yield estimates in excess of 20 tons per acre. In view of these inaccuracies tame hay was excluded from economic analysis. Errors in acreage estimates of other crops may have affected production function estimates also, to what extent could not be quantified.

Correlations among variables of crop yield technology, i.e. variety improvement, fertilizer application, fertilizer response, and other crop yield variables included as time trend variables, were high and tested statistically significant at the one percent level for all corn data sets. To avoid erroneous estimates, caused by multicollinearity, coefficients of variety indices and plant nutrient response were estimated independently and then incorporated in state crop production functions. This procedure appeared to yield satisfactory results but did probably not account sufficiently for interaction effects between different variables of crop yield technology which can be largely attributed to the form of the production function. Interaction effects could possibly be incorporated in alternative models of functions but would necessitate more accurate knowledge of existing interactions between variables. These additional refinements would be most productive if superior estimates of other crop yield variables, unidentified in this study, could also be quantified and included in future analyses.

On the basis of production function estimates, subject to specified limitations, contributions of major crop yield variables to crop yield change over time were estimated. The analysis covered the greater part of the last two decades in all cases. Yield changes of nine crops, i.e. wheat, oats, soybean, barley, flax, cotton, grain sorghum, corn and tame hay; were analyzed. By holding weather and short run acreage indices fixed, annual changes in expected crop yields were attributed to variety improvement, fertilizer use and other crop yield variables. In aggregating changes in state crop yields annual and cumulative effects of regional specialization on total production were estimated. Impact of crop yield technology and regional specialization on U.S. crop productions was estimated for corn, oats, soybeans, grain sorghum and flax in terms of dollar value added to gross return to U.S. Agriculture in 1960. According to these estimates crop yield technology applied to corn added most, over two billion dollars annually, while crop yield technology of flax resulted in a net loss of approximately five million dollars. Finally expected and economic optimum yields of individual crops were compared annually over the last two decades. It was concluded that the incentive to produce more per acre by more extensive fertilizer use was diminished with respect to all major crops.

Even if the incentive to produce more per acre by higher rates of fertilizer application was reduced it did not imply that yields per acre would fail to advance in the future. Introduction and adoption of new crop yield technology can be expected to raise yields further and thereby make higher rates of fertilizer application more profitable. Also long run trends in prices, if favorable to farmers, will induce farmers to produce more per acre by application of more fertilizer and use of other resource inputs. Whether or not the current trend of substitution of yield increasing inputs for cropland will continue depends largely on future development of new technology and changes in price structure. However, in a modern capitalistic system progress is not conditioned by monetary incentives alone. Farmers prefer higher crop yields over lower yields even if additional monetary gains do not appear to justify additional efforts. Research workers engaged in developing new crop yield technologies work with enthusiasm even though they can not expect to be recipients of future returns which may accrue from research developments. What appears to make the system so productive is a unique combination of monetary incentives, private enterpreneurship, government sponsored research and the inherent drive of the people to do better.

CHAPTER VII

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CHAPTER VIII

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MISCELLANEOUS

<u>Crop acres and production</u>

U.S.D.A. Washington, D.C. Stat. Bul. 101, June 1951; 108, Mar. 1952; 158, Feb. 1955; 164, June 1955; 185, June 1956;

U.S.D.A. (Cont.) 211, June 1957; 213, June 1957; 238, Oct. 1958; 241, Jan. 1959; 244, Feb. 1959; 251, June 1959; 254, July 1959; 264, April 1960; 290, June 1961; 311, May 1962; 320, July 1962.

———— Crop Production, annual summaries. 1956, Dec. 1956; 1957, Dec. 1957; 1958, Dec. 1958; 1959, Dec. 1959; 1960, Dec. 1960; 1961, Dec. 1961.

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X. APPENDIX A

Table A.1. Annual barley variety indices by states, base period 1947 to 1949[a]

Year	Minnesota	Montana	Nebraska	N. Dakota	S. Dakota	Wisconsin
			Barley Variety Indices			
1940			1.00			
1941			1.00			
1942		.88	1.00			
1943	1.00	.89	1.00	.99	.99	1.00
1944	1.00	.90	1.00	.99	.99	1.00
1945	1.00	.93	1.00	.99	.99	1.00
1946	1.00	.97	1.00	1.00	.99	1.00
1947	1.00	1.00	1.00	1.00	.99	1.00
1948	1.00	1.00	1.00	1.00	1.00	1.00
1949	1.00	1.00	1.00	1.00	1.01	1.01
1950	.99	1.00	1.00	1.00	1.01	1.05
1951	1.00	1.00	1.00	1.00	1.01	1.06
1952	.99	1.00	1.00	1.00	1.00	1.05
1953	.99	1.00	1.02	1.00	1.01	1.05
1954	.99	.99	1.03	1.01	1.01	1.03
1955	.99	1.00	1.05	1.01	1.01	1.02
1956	.99	1.00	1.06	1.01	1.02	1.03
1957	1.01	1.00	1.06	1.05	1.03	1.02
1958	1.03	1.00	1.07	1.09	1.03	1.02
1959	1.04	1.01	1.08	1.12	1.05	1.02
1960	1.04	1.01	1.09	1.14	1.08	1.03

[a]Source: References; Barley.

Table A.2. Annual cotton variety indices by states, base period 1947 to 1949[a]

Year	Arkansas	Cotton Variety Indices Mississippi	Oklahoma	Texas
1939	.97	.98	1.04	
1940	.97	.98	1.03	.93
1941	.97	.98	1.03	.94
1942	.98	.98	1.02	.95
1943	.98	.98	1.00	.96
1944	.98	.99	.99	.97
1945	.98	1.00	1.00	.98
1946	.98	1.00	1.00	.99
1947	.99	1.00	1.00	.99
1948	1.00	1.00	1.00	1.00
1949	1.01	1.00	1.00	1.00
1950	1.03	1.00	1.01	1.00
1951	1.04	1.01	1.02	.99
1952	1.04	1.01	1.01	1.01
1953	1.05	1.01	1.01	1.03
1954	1.05	1.02	1.01	1.04
1955	1.04	1.02	1.01	1.06
1956	1.03	1.02	1.00	1.07
1957	1.03	1.02	1.00	1.08
1958	1.04	1.02	1.00	1.08
1959	1.05	1.03	1.01	1.09
1960	1.10	1.05	1.00	1.09
1961	1.13	1.06	1.00	1.10

[a]Source: References; Cotton.

Table A.3. Annual flax variety indices by states, base period 1947 to 1949[a]

Year	Flax Variety Indices Minnesota	North Dakota	South Dakota
1939			.92
1940			.92
1941			.92
1942			.92
1943			.93
1944	.97	1.00	.94
1945	1.01	1.01	.96
1946	1.02	1.01	.99
1947	1.01	1.01	1.00
1948	1.00	1.00	1.00
1949	.99	.99	1.00
1950	.98	.98	1.01
1951	.98	.97	1.03
1952	.99	.96	1.03
1953	1.00	.95	1.02
1954	1.01	.95	1.02
1955	1.01	.95	1.02
1956	1.01	.94	1.01
1957	1.01	.94	.99
1958	1.00	.93	.98
1959	1.01	.92	.97
1960	1.01	.91	.97
1961	1.01	.91	

[a]Source: References; Flax.

Table A.4. Annual grain sorghum variety indices by states, base period 1947 to 1949[a]

Year	Grain Sorghum Variety Indices Kansas	Nebraska	Oklahoma	Texas
1939	1.05	1.05		.92
1940	1.04	1.05		.92
1941	1.02	1.04		.94
1942	1.01	1.05		1.01
1943	1.00	1.05		1.00
1944	1.00	1.05	1.00	1.01
1945	.99	1.04	1.00	1.01
1946	.99	1.03	1.00	1.01
1947	1.00	1.00	1.00	1.00
1948	1.00	1.00	1.00	1.00
1949	1.00	1.00	1.00	1.00
1950	1.01	1.00	1.00	1.00
1951	1.02	.99	1.00	1.00
1952	1.04	.99	1.00	1.00
1953	1.05	.99	1.00	1.00
1954	1.06	.98	1.00	1.00
1955	1.06	.98	1.00	1.00
1956	1.07	.98	1.01	1.00
1957	1.10	1.03	1.01	1.04
1958	1.23	1.09	1.05	1.12
1959	1.35	1.15	1.20	1.15
1960	1.39	1.17	1.33	1.20
1961	1.40	1.19	1.36	1.22

[a]Source: References; Grain Sorghum.

Table A.5. Annual oats variety indices by states, base period 1947 to 1949[a]

Year	Illinois	Indiana	Iowa	Kansas	Michigan	Minnesota	Missouri
1942	1.02	.98	.96	1.00	.97	.94	1.00
1943	1.00	.96	.92	1.00	.97	.91	.99
1944	.98	.95	.92	.99	.97	.91	.98
1945	.97	.96	.92	.99	.97	.91	.97
1946	.97	.96	.92	.99	.99	.91	.97
1947	.96	.97	.95	1.00	1.00	.97	.99
1948	1.02	1.01	1.02	1.02	1.00	1.00	1.00
1949	1.02	1.02	1.03	.98	1.00	1.03	1.01
1950	1.02	1.03	1.03	.99	1.00	1.06	1.02
1951	1.02	1.02	1.05	.97	1.00	1.08	1.03
1952	1.02	1.02	1.08	.96	1.00	1.09	1.04
1953	1.02	1.02	1.10	.99	1.04	1.09	1.07
1954	1.03	1.02	1.11	1.03	1.07	1.11	1.09
1955	1.04	1.03	1.11	1.04	1.05	1.14	1.10
1956	1.05	1.03	1.11	1.04	1.13	1.18	1.10
1957	1.06	1.04	1.11	1.03	1.18	1.23	1.10
1958	1.07	1.04	1.11	1.04	1.19	1.24	1.11
1959	1.09	1.04	1.11	1.03	1.17	1.26	1.10
1960	1.09	1.04	1.11	1.03	1.22	1.26	1.10
1961	1.09		1.11	1.03			1.10
	Nebraska	N. Dakota	Ohio	Oklahoma	S. Dakota	Texas	Wisconsin
1942	.97	.97	.99	.89	.98	.98	.88
1943	.97	.97	.99	.90	.97	.98	.91
1944	.97	.97	.98	.89	.98	.99	.93
1945	1.00	.98	.97	.91	.99	.99	.93
1946	1.00	.98	.96	.94	.99	1.00	.93
1947	1.00	.99	.95	.97	1.00	1.00	.95
1948	1.00	1.00	1.02	1.01	1.00	1.00	.99
1949	1.00	1.01	1.03	1.02	1.00	1.00	1.06
1950	1.01	1.03	1.05	1.03	1.00	1.00	1.07
1951	1.02	1.03	1.05	1.04	1.00	1.00	1.08
1952	1.01	1.04	1.05	1.05	1.00	1.00	1.09
1953	1.02	1.04	1.05	1.05	1.00	1.00	1.11
1954	1.03	1.05	1.05	1.09	1.02	1.01	1.11
1955	1.04	1.06	1.05	1.14	1.04	1.01	1.13
1956	1.04	1.07	1.07	1.22	1.07	1.01	1.17
1957	1.04	1.07	1.07	1.22	1.09	1.01	1.19
1958	1.04	1.06	1.07	1.23	1.07	1.01	1.20
1959	1.05	1.07	1.07	1.24	1.07	1.00	1.22
1960	1.05	1.07	1.08	1.24	1.06	1.02	1.24
1961			1.09	1.23	1.06	1.05	1.24

[a]Source: References; Oats.

Table A.6. Annual soybean variety indices by states, base period 1947 to 1949[a]

	Soybean Variety Indices					
Year	Arkansas	Illinois	Indiana	Iowa	Louisiana	Michigan
1941		.91	.95	.94		
1942		.91	.95	.94		.97
1943	.90	.91	.95	.94	.88	.96
1944	.94	.92	.96	.93	.91	.97
1945	.97	.93	.97	.94	.95	.96
1946	.97	.97	.97	.96	.97	.97
1947	.99	1.00	.99	.99	.98	.98
1948	1.00	1.00	1.00	1.00	1.00	1.02
1949	1.01	1.01	1.02	1.01	1.02	1.01
1950	1.02	1.02	1.05	1.05	1.03	1.05
1951	1.04	1.03	1.06	1.07	1.05	1.06
1952	1.05	1.03	1.07	1.06	1.06	1.06
1953	1.06	1.04	1.08	1.06	1.06	1.06
1954	1.07	1.05	1.08	1.06	1.06	1.05
1955	1.08	1.06	1.11	1.06	1.05	1.05
1956	1.08	1.07	1.11	1.06	1.08	1.09
1957	1.10	1.08	1.13	1.06	1.08	1.11
1958	1.11	1.09	1.13	1.06	1.08	1.16
1959	1.11	1.09	1.14	1.06	1.14	1.15
1960	1.13	1.09	1.15	1.06	1.05	1.16

Year	Minnesota	Mississippi	Missouri	Ohio	Wisconsin
1941			.88	.95	
1942	.97		.88	.96	1.00
1943	.97	.78	.90	.96	1.00
1944	.97	.84	.92	.96	1.00
1945	.97	.94	.96	.97	1.00
1946	.98	.97	.99	.98	1.00
1947	.99	.99	1.00	.99	1.00
1948	1.00	1.01	1.00	1.00	1.00
1949	1.00	1.00	1.00	1.01	1.00
1950	1.01	1.00	.99	1.04	1.01
1951	1.01	1.00	.99	1.06	1.03
1952	1.02	1.00	.98	1.07	1.04
1953	1.06	.99	.99	1.08	1.06
1954	1.12	.98	1.00	1.09	1.07
1955	1.11	.98	.99	1.12	1.09
1956	1.12	1.05	1.02	1.12	1.14
1957	1.17	1.07	1.03	1.13	1.17
1958	1.19	1.07	1.04	1.13	1.19
1959	1.20	1.07	1.07	1.13	1.23
1960	1.21	1.06	1.07	1.14	1.24

[a]Source: References; Soybeans.

Table A.7. Annual wheat variety indices by states, base period 1947-1949[a]

	Wheat Variety Indices					
Year	Alabama	Georgia	Illinois	Indiana	Iowa	Kansas
1929			.95		.93	.90
1930			.95		.93	.90
1931			.95		.93	.90
1932			.95		.93	.90
1933			.94		.93	.90
1934			.94		.93	.90
1935			.94		.93	.91
1936			.94		.94	.91
1937			.94		.94	.92
1938			.95		.94	.93
1939	.90	.90	.95	.98	.94	.93
1940	.90	.90	.94	.98	.95	.94
1941	.90	.91	.94	.98	.96	.95
1942	.91	.92	.94	.98	.96	.95
1943	.91	.92	.94	.98	.97	.96
1944	.91	.93	.93	.98	.97	.96
1945	.94	.94	.95	.99	.98	.97
1946	.96	.96	.97	.99	.99	.98
1947	.98	.98	.98	1.00	.99	.99
1948	1.00	1.00	1.00	1.00	1.00	1.00
1949	1.02	1.02	1.02	1.00	1.01	1.01
1950	1.04	1.03	1.04	1.00	1.01	1.01
1951	1.06	1.05	1.06	1.00	1.01	1.01
1952	1.08	1.07	1.09	1.00	1.01	1.01
1953	1.10	1.09	1.09	1.00	1.01	1.01
1954	1.12	1.10	1.10	1.00	1.01	1.01
1955	1.14	1.11	1.11	1.01	1.01	1.01
1956	1.15	1.12	1.11	1.03	1.02	1.01
1957	1.17	1.13	1.12	1.05	1.03	1.02
1958	1.18	1.14	1.12	1.07	1.03	1.02
1959	1.20	1.16	1.12	1.08	1.04	1.02
1960	1.20	1.17	1.12	1.09	1.04	1.02
1961			1.13		1.04	
	Michigan	Minnesota	Montana	Nebraska Winter Wheat	Nebraska Spring Wheat	N. Dakota
1929		.72	.94	.92	.74	.88
1930		.73	.94	.92	.76	.88
1931		.73	.94	.92	.78	.88
1932		.73	.94	.92	.79	.87
1933		.73	.94	.92	.81	.87

[a]Source: References; Wheat.

Table A.7 (Continued)

Year	Michigan	Minnesota	Montana	Nebraska Winter Wheat	Nebraska Spring Wheat	N. Dakota
	Wheat Variety Indices					
1934		.73	.94	.92	.83	.87
1935		.76	.95	.93	.84	.89
1936		.79	.95	.93	.86	.90
1937		.83	.95	.93	.87	.92
1938		.86	.96	.94	.89	.93
1939	.95	.89	.96	.94	.90	.95
1940	.96	.91	.97	.94	.91	.95
1941	.96	.92	.97	.95	.92	.96
1942	.96	.94	.98	.95	.92	.97
1943	.97	.96	.98	.95	.93	.98
1944	.97	.97	.99	.96	.94	.98
1945	.98	.98	.99	.97	.96	.99
1946	.99	.99	1.00	.98	.97	.99
1947	.99	.99	1.00	.99	.99	1.00
1948	1.00	1.00	1.00	1.00	1.00	1.00
1949	1.01	1.01	1.00	1.01	1.01	1.00
1950	1.01	1.03	1.00	1.01	1.03	1.00
1951	1.01	1.04	1.01	1.01	1.04	1.00
1952	1.01	1.06	1.01	1.01	1.05	1.00
1953	1.01	1.08	1.01	1.02	1.06	1.00
1954	1.01	1.10	1.02	1.02	1.07	1.00
1955	1.04	1.14	1.01	1.02	1.07	1.02
1956	1.06	1.18	1.01	1.02	1.06	1.04
1957	1.08	1.21	1.01	1.02	1.06	1.07
1958	1.11	1.25	1.01	1.02	1.06	1.08
1959	1.13	1.29	1.02	1.02	1.06	1.11
1960	1.16	1.29	1.02	1.02	1.06	1.12
1961			1.02			

Year	N. Carolina	Ohio	Oklahoma	Pennsylvania	S. Dakota Winter Wheat	S. Dakota Spring Wheat
1929			.87		.95	.94
1930			.87		.95	.93
1931			.87		.95	.92
1932			.87		.95	.91
1933			.87		.95	.90
1934			.87		.95	.89
1935			.87		.95	.90
1936			.87		.95	.91
1937			.88		.95	.92
1938			.88		.95	.94
1939	1.03	.95	.88	.93	.95	.95

Table A.7 (Continued)

Year	N. Carolina	Ohio	Oklahoma	Pennsylvania	S. Dakota Winter Wheat	S. Dakota Spring Wheat
			Wheat Variety Indices			
1940	1.02	.96	.88	.93	.96	.95
1941	1.02	.97	.89	.94	.98	.95
1942	1.01	.98	.89	.94	.99	.96
1943	1.00	.98	.89	.95	1.01	.96
1944	1.00	.99	.90	.95	1.02	.96
1945	1.00	.99	.92	.96	1.02	.97
1946	1.00	1.00	.95	.98	1.01	.98
1947	1.00	1.00	.97	.99	1.01	.99
1948	1.00	1.00	1.00	1.00	1.00	1.00
1949	1.00	1.00	1.03	1.01	.99	1.01
1950	1.04	1.01	1.03	1.01	1.00	1.02
1951	1.08	1.01	1.03	1.02	1.01	1.03
1952	1.13	1.02	1.03	1.02	1.02	1.04
1953	1.17	1.02	1.04	1.02	1.02	1.05
1954	1.21	1.03	1.04	1.02	1.03	1.06
1955	1.22	1.03	1.05	1.02	1.03	1.07
1956	1.23	1.03	1.05	1.03	1.03	1.08
1957	1.24	1.04	1.06	1.03	1.03	1.09
1958	1.26	1.04	1.06	1.03	1.03	1.10
1959	1.27	1.04	1.07	1.03	1.03	1.11
1960	1.28	1.04	1.07	1.03	1.03	1.11

Year	Tennessee	Texas	Virginia	W. Virginia	Wisconsin
1929		.94			
1930		.94			
1931		.94			
1932		.94			
1933		.94			
1934		.94			
1935		.95			
1936		.95			
1937		.95			
1938		.95			
1939	.99	.95	.96	.92	.87
1940	.99	.96	.96	.92	.87
1941	.99	.96	.95	.92	.88
1942	.98	.96	.95	.93	.88
1943	.98	.97	.94	.93	.88
1944	.98	.97	.94	.93	.88
1945	.98	.98	.95	.95	.91
1946	.99	.99	.97	.97	.94
1947	1.00	.99	.98	.98	.97
1948	1.00	1.00	1.00	1.00	1.00
1949	1.01	1.01	1.02	1.02	1.03

Table A.7 (Continued)

Year	Tennessee	Texas	Virginia	W. Virginia	Wisconsin
	Wheat Variety Indices				
1950	1.02	1.00	1.03	1.02	1.03
1951	1.04	1.00	1.05	1.03	1.03
1952	1.06	1.00	1.07	1.03	1.03
1953	1.08	1.00	1.09	1.04	1.03
1954	1.10	1.00	1.11	1.04	1.03
1955	1.11	1.00	1.12	1.05	1.03
1956	1.13	1.00	1.12	1.06	1.03
1957	1.13	1.00	1.13	1.06	1.04
1958	1.14	.99	1.13	1.06	1.04
1959	1.15	.99	1.14	1.07	1.04
1960	1.16	.99	1.14	1.07	1.04

Table A.8. Relative test yields and acreage distribution of barley varieties, Minnesota, 1943 to 1960[a]

Variety	Lake States Test Yields: No. of Tests	Lake States Test Yields: % of Wisc. 38	Estimated Percentage of Acreage Planted to Specified Varieties: 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Trebi	24	113.6					3	5	5	5														
Manchuria	114	92.9					3	5	5	5	2	1	1	1	1									
Wisc. 38	114	100.0					85	80	70	40	16	12	6	4	3	2	2	1	[b]					
Kindred	91	98.8						2	10	40	60	65	75	80	77	91	92	93	95	97	80	47	31	36
Mars	114	107.0								1	14	10	2	2	1	[b]								
Tregal	17	120.1									1													
Montcalm	70	103.2										2	10	10	5	3	3	3	2					
Moore	49	108.6												1	10									
Vantage	31	115.5																1	1	1				
Forrest	49	100.7																			1	16	17	8
Parkland	41	104.6																			2	4	4	4
Traill	55	108.7																			15	30	48	50
Oderbrucker							3	2	2															
O.A.C. 21								2	2	4	1	2	1											
Unspecified							6	4	6	5	6	8	5	2	3	4	3	2	2	2	2	3	0	2

[a]Source: References; Barley, Minnesota.

[b]Less than .5 percent.

Table A.9. Relative test yields and acreage distribution of barley varieties, Montana, 1942 to 1961[a]

Variety	Montana Test Yields No. of Tests	Montana Test Yields % of Compana	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Hannchen	16	100.2				13	10	5	2																
Spartan	26	95.6				15	13	10	5	2	1														
Trebi	38	90.3				40	35	30	25	10	5	1	1	b	b										
Horn	27	75.4				30	29	27	20	10	4	3	2	2	2	2	2	2	2	2	2	2	3	3	2
Compana	63	100.0				1	9	20	40	65	73	84	90	90	87	86	87	86	80	74	75	67	59	59	66
Atlas	29	106.0					2	5	2	b															
Glacier	64	113.4					b	1	5	10	15	10	5	4	3	2	2	2	2	b	b	b	b	b	
Frontier	13	96.7											b	1	2	1	b								
Moore	14	85.3												b	1	1	b								
Titan	72	103.5												1	5	6	5	4	5	5	5	6	4	3	2
Montcalm	14	87.5														b	b	1	1	1	b	b	b	b	b
Sanalta	30	88.1														b	1	1	1	1	1	1	b	b	b
Vantage	48	103.9															b	1	8	15	13	11	9	5	4
Moravian	4	92.3																		b	1	1	2	1	1
Betzes	39	107.1																			b	9	19	27	21
Freja	47	105.7																				b	1	1	1
Traill	27	95.8																					b	b	b
Unitan	19	105.5																							1
Unspecified						1	2	2	1	3	2	2	2	2	0	2	3	3	1	2	3	3	3	1	2

[a]Source: References; Barley, Montana.

[b]Less than .5 percent.

Table A.10. Relative test yields and acreage distribution of barley varieties, Nebraska, 1940 to 1961[a]

Variety	Nebraska Test Yields No. of Tests	Nebraska Test Yields % of Trebi	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Spartan	113	90.4	30	30	30	30	30	30	30	30	30	30	35	35	35	35	35	35	30	28	27	26	24	22	20
Trebi	119	100.0	20	20	20	20	20	20	20	20	20	15	15	15	15	10	10	10	10	8	7	6	5	5	3
Plains	105	100.7											1	2	5	5	10	10	10	8	8	8	4	3	2
Custer	92	109.6														1	5	10	15	20	22	26	28	30	30
Otis	70	107.3																	1	2	3	4	6	8	10
Hiland	12	100.0																				1	1	1	1
Kearney																1	2	3	4	4	5	8	12	14	14
Compana																	1	2	2	3	4	2	2	1	1
Dicktoo																		2	3	5	8	12	12	12	12
Meimi																							1	1	3
Hudson																									1
Unspecified			50	50	50	50	50	50	50	50	50	55	49	48	45	48	37	28	25	22	16	7	5	3	3

[a]Source: References; Barley, Nebraska.

Table A.11. Relative test yields and acreage distribution of barley varieties, North Dakota, 1943 to 1961[a]

	North Dakota Test Yields		Estimated Percentage of Acreage Planted to Specified Varieties																				
	No. of Tests	% of Wisc. 38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Trebi	37	125.4					14	13	12	10	7	5	2	2	2	2	1	1	1	b	b				
Plush	11	84.2					16	14	13	10	8	6	4	2	b	b	b	b	b	b	b	b			
Spartan	26	89.1					4	3	2	2	2	1	b	b	b	b	b	b	b	b	b	b			
Manchuria	72	95.8					16	14	12	10	8	5	2	2	2	2	1	1	1	1	1	b	b		
Wisc. 38	66	100.0					37	34	29	25	19	14	9	7	4	2	2	1	1	b	b	b	b		
Kindred	46	99.9					7	15	24	29	39	50	60	64	67	71	74	76	78	81	62	43	30	24	20
Montcalm	41	100.1						b	1	3	6	8	10	11	12	14	10	8	4	2	1	b			
Tregal	27	116.5						b	1	6	6	5	4	4	4	4	4	4	4	4	4	5	4	4	4
Vantage	16	121.4						b	1	1	1	1	1	1	1	b	2	3	5	6	6	7	6	6	6
Moore	21	100.4									b	1	2	2	2	2	2	2	2	b	b				
Husky	4	122.5														b	1	1	1	1	1	2	1	1	1
Parkland	7	108.6																	b	1	2	2	2	3	4
Traill	7	120.6																	1	2	17	35	52	57	62
Forrest	4	108.8																			b	1	2	1	
Oderbrucker							4	4	3	2	2	2	1	b											
O.A.C. 21							2	2	2	2	2	2	2	1	b	b									
Betzes																							b	1	
UM 570																					1	2	2	2	
Unspecified							0	1	0	0	0	0	3	4	6	3	3	3	2	2	5	3	1	1	3

[a]Source: References; Barley, North Dakota.

[b]Less than .5 percent.

Table A.12. Relative test yields and acreage distribution of barley varieties, South Dakota, 1943 to 1960[a]

Variety	South Dakota Test Yields No. of Tests	% of Odessa	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Velvet	5	64.2					5	5	4	4	4	3	2	1											
O.A.C. 21	1	76.4					3	3	3	3	4	6	7	5	2										
Trebi	41	114.4					4	4	3	3	3	2	2	1	1										
Spartan	46	86.9					47	43	39	36	26	16	7	7	7	7	8	8	9	10	10	10	7	6	
Kindred	47	87.3					2	5	9	12	20	28	35	43	51	59	57	55	53	51	50	49	41	36	
Wisc. 38	51	93.4					14	14	14	14	12	11	10	8	4	2	2	2	3	3	2	1	1	2	
Odessa	63	100.0					13	13	14	14	12	11	10	9	9	9	9	9	8	8	6	5	5	3	
Montcalm	12	104.2									2	4	6	6	5	4	4	3	3	3	2				
Feebar	46	106.2									1	2	3	3	3	3	4	4	5	6	4	1	1	1	
Plains	53	107.7										1	2	2	3	3	4	5	6	7	6	4	4	4	
Plush	3	50.6											b												
Manchuria	16	93.4											1												
Tregal	22	100.3											1												
Traill	16	103.7																			8	15	27	32	
Liberty	17	120.7																			1	2	3	7	
Parkland	2	83.9																					1	1	
Dryland										7	6	5	4	2	1										
Beecher											b	b	1	b	b										
Glaborn											b	b	b	b	b										
Unspecified							12	13	14	7	10	11	9	13	14	13	12	14	13	12	11	13	10	8	

[a]Source: References; Barley, South Dakota.

[b]Less than .5 percent.

Table A.13. Relative test yields and acreage distribution of barley varieties, Wisconsin, 1939 to 1961[a]

Variety	Lake States Test Yields No. of Tests	% of Wisc. 38	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Wisc. 38	114	100.0	90	90	90	90	90	80	70	69	68	64	51	25	5	1									
Manchuria	114	92.9								1			4												
Kindred	91	98.8								1	2	5		5	10	20	20	25	30	30	35	31	30	30	25
Moore	49	108.6										1	10	50	60	48	50	30	17	20	20	20	20	20	20
Montcalm	70	103.2													10	19	20	30	35	30	20	15	15	10	10
Fox	38	102.4																			10	11	10	5	5
Traill	55	108.7																						10	20
Oderbrocker			10	10	10	10	10	20	25	20	20	20	17	15	15	9	10	15	15	20	15	18	20	20	20
O.A.C. 21									5	8	10	10		5											
Unspecified			0	0	0	0	0	0	0	1	0	0	18	0	0	3	0	0	3	0	0	5	5	5	0

[a]Source: References; Barley, Wisconsin.

Table A.14. Relative test yields and acreage distribution of cotton varieties, Arkansas, 1941 to 1961[a]

	Arkansas Test Yields Test Period	No. of Tests	% Delta-pine 15	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Stoneville I	41-49	75	94.9	30	30	30	30	32	35	34	30	24												
Stoneville II	50-61	69	105.3										20	15	15	14	13	7	5	3	3	3	2	2
Rowden	41-52	86	87.6	36	34	33	32	31	28	21	15	12	9	7	3	1	1	1	1					
Hibred	41-52	81	104.2	15	15	13	12	11	10	8	6	4	3	2	1	1	1	1	1					
Deltapine	41-60	80	100.0	11	12	13	14	15	20	30	40	47	54	63	70	67	68	72	69	66	63	50	34	16
Empire	45-60	87	104.4								1	3	6	7	6	5	5	5	4	3	4	3	2	2
Pauls	44-56	58	96.8									2	1	1	2	1	1	1	b					
Delfos	41-60	115	95.0												b	b	2	7	13	20	18	28	19	18
Fox	50-60	68	107.2												b	7	7	3	3	3	3	3	4	3
Dixie King	55-60	34	107.1																		b		b	1
Rex	57-60	29	119.7																		4	11	24	32
Dpl. Sm. Leaf	57-60	28	111.5																			b	11	24
Unspecified				8	9	11	12	11	7	7	8	8	7	5	3	4	2	3	4	5	5	2	4	2

[a]Source: References; Cotton, Arkansas.

[b]Less than .5 percent.

Table A.15. Relative test yields and acreage distribution of cotton varieties, Mississippi, 1939 to 1961[a]

Variety	Mississippi Test Yields: Test Period	No. of Tests	% Delta-pine 15	Estimated Percentage of Acreage Planted to Specified Varieties: 39	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Delfos I	37-43	64	82.3	10	9	8																		
Delfos II	44-48	58	92.6				8	7	5	5	5													
Delfos III	49-60	95	102.5									5	3	3	2	2	2	3	4					
Coker I	39-53	115	94.6	6	6	6	6	6	6	6	6	6	8	10	8	7								
Coker II	54-60	32	107.7														6	4	4	5	5	2	3	3
Stoneville I	37-50	135	98.7	15	15	15	15	15	15	15	15	15	9											
Stoneville II	51-55	40	104.5											7	5	4	4	4						
Stoneville III	56-60	42	110.1																3	5	2	4	7	5
Deltapine	39-60	216	102.0	50	55	60	65	70	70	70	70	70	72	77	81	82	79	80	80	76	79	71	46	27
Empire	44-60	131	104.4							2	2	2	1	2	2	2	2	2	2	3	2	2	1	2
Coker Staple	37-54	37	100.3										2	1	1		1	1						
Fox	37-60	75	105.8													1	4	3	3	4	3	4	7	3
Dixie King	39-60	52	110.9																	1	1	3	2	3
Dpl. Sm. Leaf	57-60	32	109.4																			2	21	49
Rex	37-60	26	113.2																			1	3	3
Unspecified				19	15	11	6	2	4	2	2	2	5	0	1	2	2	3	4	6	8	11	10	5

[a]Source: References; Cotton, Mississippi.

Table A.16. Relative test yields and acreage distribution of cotton varieties, Oklahoma, 1939 to 1961[a]

Variety	Oklahoma Test Yields: No. of Tests	Oklahoma Test Yields: % of Hibred	Estimated Percentage of Acreage Planted to Specified Varieties: 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Acla 8	7	84.8	10	7	2																				
Mebane 140	15	107.2	8	8	5	2																			
Acala 892	9	99.2	6	8	9	5	2																		
Cluster	12	72.1	5	6	8	10	12	14	12	11	10	9	8	4	4	5	5	5	4	2					
Rowden	18	84.3	10	17	17	16	16	16	12	10	11	10	10	8	3	1	1	1							
Lockett 140	15	94.7	2	2	2	4	5	5	5	8	8	9	9	8	7	6	6	5	3	1					
Hibred, ½+½	19	99.6	19	21	25	22	20	18	16	15	14	13	13	13	14	12	10	12	13	3					
North Star	44	85.4	2	2	2	4	5	8	8	10	12	16	17	17	15	14	10	10	11	19	14	11	8	18	12
Lankart	69	91.1	2	2	5	6	8	10	12	13	15	18	20	20	20	30	33	33	36	40	41	53	48	42	54
Stoneville	44	95.6	12	12	14	16	14	15	15	13	12	11	10	11	14	7	12	13	10	12	8	5	5	5	6
Deltapine	43	96.1	10	10	10	10	12	12	14	14	13	11	12	12	13	5	9	8	8	7	7	5	5	5	5
Lockett Stp.	38	88.4												2	2	3	6	5	5	4	5	2	2	3	3
West.Stpr.	60	90.1																			7	8	13	12	4
Parrot	64	90.8																			6	7	9	9	9
Gregg	32	88.7																					1	1	2
Unspecified			14	5	1	5	6	2	6	6	5	3	1	5	8	17	8	8	10	12	12	9	9	5	5

[a]Source: References; Cotton, Oklahoma.

Table A.17. Relative test yields and acreage distribution of cotton varieties, Texas, 1950 to 1961[a]

	Test Yields in Percent of Hibred by Cotton Districts								Estimated Percentage of Acreage Planted to Specified Varieties											
Variety	No. of Tests	Distr. 1	Distr. 2	Distr. 4	Distr. 5	Distr. 6	Distr. 8	Distr. 10	50	51	52	53	54	55	56	57	58	59	60	61
W. Prolific	23	94.0	100.9						4	4										
Mebane	131	97.9	98.7	108.5	84.5		89.6	72.6	14	10	6	4	5	3						
Hibred $\frac{1}{2}+\frac{1}{2}$	88	98.3	102.3	101.3	100.0				9	7	4	4	4	5						
Macha	27	93.7	93.2						10	16	17	10	5	2						
Lockett 140	97	99.6	105.9	109.4					3	4	6	12	8	5						
Rowden	151	85.5	88.1	97.0	84.3		87.8	85.4	23	20	13	11	10	5	4					
Empire	106	106.0	100.7		110.7	119.1	107.2	99.7	1	1	2	2	1	3	3					
Acala	212	95.3	98.9	97.5	89.9	120.8	89.7	84.8	2	2	6	6	5	6	8	10	9	9	8	6
Delfos	46						105.0	98.1	1	1	0	1	1	2	2	2	2	2	2	1
Deltapine	206	112.0	106.9	111.5	102.8	132.0	99.4	104.2	11	12	21	18	15	17	19	16	12	11	11	10
Qualla	46	89.2	96.6	107.2	58.6		81.5	76.1	1	2	1	4	4	4	3	2	2	2	1	1
Paymaster	66	104.6	111.7		125.2				2	2	4	7	6	10	4	8	4	5	2	3
North. Star	158	97.9	105.6	110.6	100.8		101.2	94.5	8	7	6	5	11	8	9	7	9	4	5	5
Lankart	151	101.8	117.9	112.1	101.6	83.9	94.4	87.0	2	4	5	9	18	22	31	31	36	35	36	33
W. Stormpr.	40	108.6	111.3	103.0											4	3	6	8	7	10
Lockett	39	123.7	110.3	114.1											2	2	2	1	1	1
Gregg	16	114.0	117.8														1	5	8	10
Stormking	20		120.5	108.0			107.7										2	2	1	1
Rex	17	117.1		130.2			107.4	106.8										1	1	2
TPSA	16		105.6		103.1															3
Unspecified									9	8	9	7	7	8	11	19	15	15	17	14

[a]Source: References; Cotton, Texas.

Table A.18. Relative test yields and acreage distribution of flax varieties, Minnesota, 1944 to 1961[a]

Variety	Minnesota Test Yields: No. of Tests	Minnesota Test Yields: % of Bison	Estimated Percentage of Acreage Planted to Specified Varieties: 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Bison	64	100						15	10	10	5	2	1	1											
Bolley Gold	15	104						10	8	5	5	5	2	2											
Koto	15	129						5	15	20	15	8	5	2	b										
Redwing	64	104						10	10	5	8	5	2	b	b	b									
Royal	7	97						10	8	10	8	5	8	6	3	2	2								
Crystal	30	99						2	0	b	2	3	3	6	6	2	2	2	2	b	b	b	b	b	b
Viking	15	104						12	10	5	5	2	2	1	b	b	b	b	b	b	b	b	b	b	0
Victory	37	105						5	10	12	15	12	12	12	11	10	15	11	3	3	1	1	1	1	b
B 5128	38	107						6	19	25	19	19	25	38	38	44	31	39	47	53	52	51	38	38	37
Arrow	15	110							2	5	10	8	6	3	b	b									
Dakota	26	107									6	18	18	18	22	16	5	2	b	b	b				
Sheyenne	15	94									1	2	2	2	2	2	2	2	2	2	1	2	1	b	b
Redson	15	124											2												
Rocket	25	103											2	6	6	6	3								
Marine	45	105													2	4	9	8	11	15	18	20	19	17	17
Redwood	46	114													2	10	29	31	32	23	23	16	18	16	12
Raja	12	107																b	b	b	1	b	b	b	b
Linda	19	115																4	2	2	2	2	2	2	2
Arny	18	108																				1	4	9	12
Bolley	16	110																				4	8	11	15
Unspecified								25	8	3	1	11	10	3	8	4	2	1	1	2	2	3	9	6	5

[a]Source: References; Flax, Minnesota.

[b]Less tham .5 percent.

Table A.19. Relative test yields and acreage distribution of flax varieties, North Dakota, 1944 to 1961[a]

Variety	North Dakota Test Yields: No. of Tests	North Dakota Test Yields: % of Bison	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
			Estimated Percentage of Acreage Planted to Specified Varieties																						
Bolley Golden	10	113						5																	
Crystal	29	106						5				1	1	1	1										
Royal	4	108						20	15	20	15	5	5	3	1										
Koto	10	120						5	20	20	20	5	5	3	1										
Renew	22	115						10	5	5				1	1	1									
Viking	10	113						25	20	10	10	5	5	2	1	1	1	1	1	1	1	1	1	1	1
Walsh	21	103						20	15	10	5	3	3	1	1	1	1	1	1	1	1	1	1	1	1
Victory	33	112						5	10	15	15	5	5	5	2	1	1	1	1	1	1	1	1	1	1
B 5128	23	102						5	15	20	15	15	20	30	30	30	20	30	30	30	35	30	25	25	25
Dakota	26	112									10	30	25	20	20	12									
Arrow	14	110											1	1	1	1									
Sheyenne	12	106									10	30	25	20	25	25	20	20	20	20	15	15	10	3	3
Rocket	20	105												2	2	2	2								
Redwood	47	107													1	5	20	15	15	5	5	1	3	1	1
Marine	46	99													2	10	30	20	21	30	35	32	30	25	25
Linda	12	110																2	1	1	1	1	1	1	1
Raja	14	96																				1	1	11	1
Bolley	21	96																				10	20	30	30
Arny	18	96																					1	5	5
Deoro												1	5	10	10	10	5	10	10	10	5	5	5	5	5
Minerva														1	1	1									
Norland																				1	1	2	1	1	1
Unspecified								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[a]Source: References; Flax, North Dakota.

Table A.20. Relative test yields and acreage distribution of flax varieties, South Dakota, 1939 to 1960[a]

Variety	South Dakota Test Yields: No. of Tests	South Dakota Test Yields: % of Bison	Estimated Percentage of Acreage Planted to Specified Varieties: 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Bison	27	100	50	50	50	40	30	30	20	20	10	5	2	2											
Biwing	6	103	10	10	10	10	5	5	5	1	1	1													
Bolley Golden	6	103	10	10	10	15	20	15	15	10	10	10	5	5											
Redwing	27	104	20	20	20	20	20	20	20	10	15	10	5	1	1	1									
Victory	13	112					5	5	10	10	15	20	20	20	20	20	30	25	5	5	1	1	1	1	
Arrow	5	118							5	10	20	15	10	5											
Koto	6	120					1	5	10	20	10	10	5	1											
Royal	3	95								1	2	5	10	10	5	5	5								
Crystal	10	116								1	5	5	5	10	10	5	5	5	5	1	1	1	1	1	
Dakota	9	117									1	5	10	15	25	20	10	5	1	1	1				
Redson	6	117											5												
Sheyenne	5	128											1	5	10	10	10	15	20	15	10	10	5	5	
Rocket	9	113											5	10	10	10	5								
Marine	21	104													5	10	10	20	30	40	50	55	55	50	
Redwood	21	110													1	5	10	20	20	20	20	15	15	15	
B 5128	8	120														5	5	5	10	15	10	10	5	5	
Raja	5	108																1	1	1	5	1	1	1	
Bolley	37[b]	102[b]																				5	10	10	
Arny	4	108																				1	5	10	
Unspecified			10	10	10	15	19	20	15	17	11	14	17	16	13	9	10	4	8	2	2	1	2	2	

[a]Source: References; Flax, South Dakota.
[b]Minnesota-North Dakota Test Yields.

Table A.21. Relative test yields and acreage distribution of grain sorghum varieties, Kansas, 1939 to 1961[a]

Variety	Kansas Test Yields No. of Tests	Kansas Test Yields % of Martin	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Feterita	21	99.2	2	2	2	2	1																		
Sooner	30	101.4	4	4	3	2	1																		
Day	23	98.6	3	3	4	4	4	3	1																
Kalo (Early)	65	118.8	18	15	8	6	4	3	1																
Darso	46	101.5	6	6	5	4	3	3	2	1															
Hegari	18	62.1	12	12	13	13	13	14	14	14	13	12	11	7	4	1									
Stand. Blackh.	16	95.1	2	2	3	3	4	3	3	2	1	1	1	1	1	1	1	1							
West. Blackh.	294	91.1	5	5	5	5	8	8	9	9	10	8	7	5	3	2	2	1	1	1	1				
Coes (Impr.)	23	87.7	8	8	10	12	12	10	8	6	4	4	4	4	4	4	4	3	3	3	2	2			
Martin	137	100.0	20	20	22	22	22	23	25	28	30	30	30	25	23	21	20	21	20	19	18	10	2		
Westland	115	95.1	15	18	21	22	24	28	32	35	37	40	42	49	49	45	42	46	43	40	34	19	9	4	1
Colby	83	97.2												1	2	2	2	2	2	1					
Norghum	14	79.0												1	1	2	3	1	2	2	2	1			
Combine 7078	11	109.5												1	6	11	12	12	10	9	7	5	2		
Plainsman	61	116.2														2	4	3	4	4	4	3			
Wheatland	56	93.4														2	4	4	3	2	1	2			
Midland	137	99.5															1	1	4	8	10	4	1		
White Martin	4	92.0																2	2	1	1	1			
Relaince	18	64.7																	1	2	3	1			
Redbine 60	23	101.3																		1	1	1			
Early Hegari	17	109.0																		1	1	1			
Comb. Kafir 60	36	113.0																		1	1	1			
Hybrid	44	128.6																			12	47	82	94	97
Dwarf Kafir														1	2	2	2	1							
Unspecified			5	5	4	5	4	5	5	5	5	5	5	5	5	5	3	2	5	5	2	2	4	2	2

[a]Source: References; Grain Sorghum, Kansas.

Table A.22. Relative test yields and acreage distribution of grain sorghum varieties, Nebraska, 1939 to 1961[a]

Variety	Nebraska Test Yields: No of Tests	Nebraska Test Yields: % of Martin	Estimated Percentage of Acreage Planted to Specified Varieties: 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Kalo	38	109.8	4	4	2	1																			
Sooner	31	105.3	17	17	10	10	5	5	3																
Day	50	90.0	13	12	18	17	16	17	19	10	5														
Coes	12	97.0	2	2	2	3	3	2	2	4	1	1	1	1	1	1	1								
Earley Kalo	14	111.1	64	65	68	69	76	76	66	56	20	10	10	10	8	5	2	1	1						
Midland	54	101.1							5	20	54	50	45	40	38	30	27	22	18	14	10	1	1		
Martin	89	100.0							5	10	20	39	44	49	53	64	66	68	67	71	56	38	17	8	4
Redbine 60	72	98.2															3	6	7	7	4	3	2	1	
Norghum	18	103.2															1	1	2	2	2	1	1	1	
Combine 7078	7	102.4																1	3	4	2	1	1		
Reliance	23	78.6																1	2	2	2	2	1	1	1
Hybrids	78	122.1																			24	54	77	89	95
Unspecified			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[a]Source: References; Grain Sorghum, Nebraska.

Table A.23. Relative test yields and acreage distribution of grain sorghum varieties, Oklahoma, 1939 to 1961

Variety	Oklahoma Test Yields No. of Tests	Oklahoma Test Yields % of Martin	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Feterita	18[a]	95.3[a]	2	2	3	2	4	2	2																
Darso	6	109.2	8	7	9	5	4	5	3	3	3														
West. Blackhull	6[a]	89.0[a]	18	17	17	27	18	29	24	26	27	27	26	23	23	22	24	22	21	19	23	14	8	2	1
Westland	12[a]	99.8[a]	2	5	6	5	7	5	9	8	11	11	12	14	14	11	10	12	14	11	11	14	12	2	
Martin	26	100.0	32	34	40	32	43	34	38	32	32	34	36	40	40	37	34	41	42	33	32	42	17	3	
Early Hegari	10	102.6	20	20	11	18	11	20	18	26	22	24	24	21	21	27	29	22	21	33	30	17	13	6	4
Hybrids	10	134.8																			2	11	50	87	94
Unspecified			18	15	14	11	13	5	6	5	5	4	2	2	2	3	3	3	2	4	2	2	0	0	1

[a]Hays, Kansas Test Yields.

Table A.24. Relative test yields and acreage distribution of grain sorghum varieties, Texas, 1939 to 1961[a]

Variety	Texas Test Yields: No. of Tests	Texas Test Yields: % of Martin	Estimated Percentage of Acreage Planted to Specified Varieties: 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Hegari	53	90.8	35	35	35	20	15	9	5																
Texas Blackhull	147	95.1	35	35	35	15	15	5	2																
Plainsman	102	108.5			6	28	30	22	14	18	6	9	6	5	4	3	2	1							
Caprock	51	109.9			4	15	8	9	8	7	6	4	3	4	4	4	4	3	3	3	2	1			
Westland	30	93.4				5	5	5																	
Texioca	16	118.6				1	1	1	1																
Wheatland	19	108.4				5	5	5	3	2	2	2													
Martin	105	100.0				5	15	41	60	67	80	80	81	73	73	71	72	73	74	74	63	42	28	12	3
Midland	59	97.6							1	1	1														
Combine 7078	25	100.0							5	5	5	5	10	15	15	15	15	16	16	16	13	5	5	3	2
Redbine 60	44	105.5												1	1	2	3	3	3	3	1				
Combine Kafir 60	46	107.5													1	2	2	1	1	1					
Hybrids	32	124.9																			20	50	66	85	95
Redbine 66	31	105.3												2	2	3	2	3	3	3	1				
Feterita			4	4	4	1	1	1	1																
Unspecified			26	26	16	5	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0

[a]Source: References; Grain Sorghum, Texas.

Table A.25. Relative test yields and acreage distribution of oats varieties, Illinois, 1942 to 1961[a]

	Corn Belt Test Yields		Estimated Percentage of Acreage Planted to Specified Varieties																						
Variety	No. of Tests	% of Andrew	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Gopher	98	82.6				3	2	b																	
Marion	49	90.7				11	11	12	11	10	9	4	3	2	2	1									
Columbia	84	91.7				52	47	41	33	24	16	14	10	10	6	6	6	5	5	5	2	1	1	1	1
Boone	22	80.7					3	9	10	12	14	b													
Vicland	30	81.0					7	14	18	22	27	2	1												
Tama	56	78.4						1	4	6	8	b													
Clinton 59	79	90.3							7	14	21	71	76	75	78	80	76	64	48	39	35	7	4	3	2
Control	4	104.1									2														
Ajax	21	123.3									b	1	1	1	1	1	1								
Benton	27	96.2									b	1	2	1	2	2	2	1	1	1				1	
Mindo	42	95.0										3	4	5	2	1	1	1							
Bonda	33	105.9										b	b	1	2	1	1	2	2	2	2				
Beaver	8	107.4												1	1	2									
Andrew	102	100.0												1	1	1	1	2	1						
Cherokee	20	90.5													1	1									
Nemaha	67	92.8														2	6	12	22	23	20	24	15	12	10
Mo. 0-205	58	101.4															2	5	7	4	2	1	2	1	1
LaSalle	18	83.5																1	1						
Branch	21	111.2																1		2	1	1			
Bonham	16	115.0																2	3	2	3	2	3	3	3
Clarion	25	99.1																	1	4	6	2	1	1	
Clintland	47	98.2																	3	11	18	36	45	25	18
Waubay	34	96.6																		1	1	1			
Newton	46	96.8																			3	16	19	39	42
Garry	25	103.7																			1	1	1		1

[a]Source: References; Oats, Illinois.

[b]Less than .5 percent.

Table A.25 (Continued)

Variety	Corn Belt Test Yields No. of Tests	Corn Belt Test Yields % of Andrew	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Rodney	12	84.0																				1		1	1
Minhafer	33	104.8																				1	3	9	9
Goodfield	21	95.9																							4
Clintland 60	27	102.3																							3
Shield	7	104.1																							1
Iowa 103						3	2	b																	
Iowar						5	5	4																	
Vanguard						4	2	1	b	b	b	b	b												
Clintafe																		1	1						
Dubois																						1			
Unspecified						22	21	18	17	12	3	4	3	3	4	2	4	3	5	6	6	5	6	4	5

Table A.26. Relative test yields and acreage distribution of oats varieties, Indiana, 1942 to 1960[a]

Variety	Corn Belt Test Yields: No. of Tests	Corn Belt Test Yields: % of Andrew	Estimated Percentage of Acreage Planted to Specified Varieties: 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Gopher	98	82.6				3	3	2																	
Marion	49	90.7				5	10	10	10	5	5	2													
Columbia	84	91.7				50	45	40	35	25	15	15	10	10	5										
Tama	56	78.4					1	2	2	2	1														
Boone	22	80.7					3	10	10	10	10	2													
Vicland	30	81.0					2	5	5	5	5	2													
Clinton	42	95.1						2	10	20	25	50	60	60	65	77	78	72	68	40	27	20	14	2	
Benton	27	96.2									2	10	15	15	15	15	10	10	5	5					
Bonda	33	105.9										1	1	1	1	1	1								
Ajax	21	123.3										1	2	3	1	1	1								
Andrew	102	100.0												1	1	1	1	1	1						
Mo. 0-205	58	101.4															2	5	10	10	1				
Clintland	47	98.2																	5	20	45	52	55	45	
Bentland	14	93.2																		2	5	5	5	2	
Newton	46	96.8																		5	8	16	18	25	
Putnam	27	93.6																				2	2	8	
Minhafer	33	104.8																					1	5	
Goodfield	21	95.9																						4	
Clintland 60	27	102.3																						2	
Dubois																	2	5	5	5	5	1	1	2	
Clintafe																		2	2	2					
Rodney																					b				
Waubay																					b				
Clarion																					b				
Branch																					b				
Unspecified						42	36	29	28	33	37	17	12	10	12	5	5	5	4	11	9	4	4	5	

[a]Source: References;Oats, Indiana.
[b]Less than .5 percent.

Table A.27. Relative test yields and acreage distribution of oats varieties, Iowa, 1942 to 1961[a]

	Corn Belt Test Yields		Estimated Percentage of Acreage Planted to Specified Varieties																						
Variety	No. of Tests	% of Andrew	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Gopher	98	82.6				5																			
Marion	49	90.7				45	10	10	10	9															
Tama	56	78.4				25	45	45	45	45	30	2													
Boone	22	80.7				25	45	45	45	45	30	2													
Clinton 59	79	90.3								1	40	95	90	85	60	35	20	5	4	3					
Cherokee Res.	21	93.1										1	10	13	20	22	25	26	27	28	29	30	30	31	32
Nemaha	67	92.8												1	5	8	10	15	17	20	20	20	20	20	20
Bonham	16	115.0												1	2	5	7	8	8	8	8	8	8	8	8
Shelby	44	108.5													2	3	5	5	5	6	6	6	5	5	
Benton	27	96.2													2	4	5	5	5	5	6	5	5	5	
Andrew	102	100.0													2	4	5	5	6	6	7	6	6	6	
Bonda	33	105.9													2	4	5	5	5	5	6	5	5	5	
Newton	5	96.8																			1	2	4	8	9
Minhafer	33	104.8																						5	16
Goodfield	21	95.9																							1
Burnett	33	100.5																							5
Clintland 60	27	102.3																							2
Unspecified						0	0	0	0	0	0	0	0	0	5	15	18	26	23	19	17	18	17	7	7

[a]Source: References; Oats, Iowa.

Table A.28. Relative test yields and acreage distribution of oats varieties, Kansas, 1942 to 1961[a]

	Northern Plains Test Yields		Estimated Percentage of Acreage Planted to Specified Varieties																						
Variety	No. of Tests	% of Andrew	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Columbia	61	86.3				5	5	5	4	3	2	1													
Kanota	77	89.5				70	65	65	60	50	40	25	15	15	15	10	10	10	10	10	10	5	5	5	5
Fulton	40	95.6				25	20	10	5																
Tama	33	90.5					5	20	30	30	20	10	5												
Neosho	40	96.5									5	20	5												
Osage	77	98.9									5	10	5												
Cherokee	17	93.9										5	20	30											
Clinton	32	81.3										5	30	20	10	10	5								
Nemaha	64	91.2										5	20	30	35	35	35	28	25	25	25	25	25	25	25
Cherokee Res.	33	85.0													35	35	35	28	25	25	25	25	25	25	25
Mo. 0-205	53	104.0															10	30	35	35	30	30	25	25	20
Andrew	94	100.0																			5	10	10	10	10
Minhafer	22	93.7																						5	10
Nehawka	17	94.9																							1
Unspecified						0	5	0	1	17	28	19	0	5	5	10	5	4	5	5	5	5	10	5	4

[a]Source: References; Oats, Kansas.

Table A.29. Relative test yields and acreage distribution of oats varieties, Michigan, 1939 to 1961[a]

Variety	Lake States Test Yields: No. of Tests	Lake States Test Yields: % of Andrew	Estimated Percentage of Acreage Planted to Specified Varieties: 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Richland	20	79.5	15	12	10	8	5	2																	
Wolferine	5	91.4	15	12	10	8	5	2																	
Marion	25	86.8		8	16	24	33	41	49	32	2														
Huron	17	89.1		8	15	23	31	38	46	20	2	b													
Eaton	14	90.3								46	96	95	41	43	34	29	12	5	4	4	2	1			
Kent	22	89.8										4	53	33	21	9	4								
Bonham	11	90.4										1	6	24	22	16	9	12	13	8					
Clinton	18	89.9													23	45	45			8					
Clinton 59	19	89.6																34	23						
Craig	10	104.0															27	49	16	1					
Clintland	10	96.3																	12	26	35	39	47	6	
Jackson	10	94.9																	30	20	14	7	4	b	
Garry	10	117.4																		33	49	53	34	33	
Simcoe	19	107.4																					6	b	
Clintland 60	12	103.8																						31	
Rodney	5	110.5																					8	30	
Iogold			15	12	10	8	5	2																	
Worthy			55	47	38	29	21	13	4																
Iowa 444									1																
Unspecified			0	1	1		0	2	0	2	0	0	0	0	0	1	3	0	2	0	0	0	1	0	

[a]Source: References; Oats, Michigan.

[b]Less than .5 percent.

Table A.30. Relative test yields and acreage distribution of oats varieties, Minnesota, 1939 to 1961[a]

Variety	Lake States Test Yields No. of Tests	Lake States Test Yields % of Andrew	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Gopher	42	81.5	60	60	60	50																			
Vicland	15	79.0					40	40	40	40	20	10													
Tama	25	79.1					40	40	40	40	20	10													
Mindo	18	84.0									20	20	20	10	10	10	10	5	5						
Bonda	24	95.7									20	20	20	30	25	20	20	15	5						
Clinton	18	89.9										20	40	40	35	30	30	15	5						
Andrew	45	100.0												10	10	10	10	15	20	20	10	10	5	2	
Ajax	13	109.2													10	10	10	15	20	25	15	15	10	5	
Mo. 0-205	17	101.7																5	15	10					
Shelby	12	99.3														10	10								
Branch	13	92.4																15	20	25	10	5	5	3	
Sauk	8	110.3																		5	5	5		1	
Rodney	5	110.5																		5	25	30	35	47	
Garry	10	117.4																		5	15	15	20	12	
Minland	8	102.7																			5	5			
Minhafer	17	105.4																				5	10	14	
Burnett	13	109.1																					5	4	
Cherokee	11	80.4																						1	
Minton	17	111.2																						3	
Iogold			10	10	10																				
Rusota			10	10	10																				
Anthony			10	10	10																				
Unspecified			10	10	10	50	20	20	20	20	20	20	20	10	10	10	10	15	10	5	15	10	10	8	

[a]Source: References; Oats, Minnesota.

Table A.31. Relative test yields and acreage distribution of oats varieties, Missouri, 1942 to 1961[a]

Variety	Corn Belt Test Yields		Estimated Percentage of Acreage Planted to Specified Varieties																						
	No. of Tests	% of Andrew	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Boone	22	80.7				2	5	10	15	15	8	5	2	1	1										
Fulghum		81.6				5	5	2	2	2	2	1	1	1	1	1									
W. Fulghum		85.2				3	5	3	3	3	1	1	1	1	1	1									
Columbia	84	91.7				83	75	70	62	57	66	59	51	44	29	18	12	3	2	2	1	1	1	1	1
Tama	56	78.4					2	5	8	10	5	3	1	1											
Mindo	42	95.0									1	5	10	12	12	10	6	3	1						
Clinton	42	95.1									1	8	15	15	15	15	12	8	4	4	4	3	3	2	1
Cherokee	20	90.5											1	5	8	8	6	4	4	4					
Nemaha	67	92.8												1	3	2									
Andrew	102	100.0												1	3	8	15	15	15	15	15	15	15	10	10
Mo. 0-200	38	98.9													1	3	5	1							
Mo. 0-205	58	101.4													2	10	25	50	61	61	61	59	53	45	43
Clintland	47	98.2																		1	1	2	2	4	5
Cherokee Res.	21	93.1																			4	4	4	4	4
Minhafer	33	104.8																				2	6	7	6
Macon	40	96.6																					1	5	7
Newton	46	96.8																					4	5	5
Nodaway	17	95.8																							1
Dubois																			1	2	4	5	6	7	6
Forkedeer						2	3	5	5	5	7	8	8	8	9	9	9	7	6	5	3	2	1		
Unspecified						5	5	5	5	8	9	10	10	10	15	15	10	9	6	6	7	7	4	10	11

[a]Source: References; Oats, Missouri.

Table A.32. Relative test yields and acreage distribution of oats varieties, Nebraska, 1942 to 1960[a]

Variety	Northern Plains Test Yields: No. of Tests	Northern Plains Test Yields: % of Andrew	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
			Estimated Percentage of Acreage Planted to Specified Varieties																						
Iogold	12	77.1				27	20	20	12	13	11	10	10	9											
Kanota	77	89.5				27	20	20	12	13	11	10	10	9											
Boone	16	90.4				5	5	5	8	5	5	5	3	3	1	1									
Kherson	26	83.9				10	10	8	8	5	5	5	3	3	3	3	2	2	1	1	1	1	1	1	
Nebr. 21	5	94.7				10	6	6	4	4	2	2	1	1	b	b	b	b	b	b	b	b	b	b	
Marion	46	95.2				1	1	2	2	2	3	3	5	5	8	8	10	12	12	12	11	10	10	10	
Brunker	39	96.2				10	10	10	8	8	8	8	6	6	6	5	4	3	3	3	3	3	3	3	
Trojan	39	85.7					18	19	12	13	11	11	11	9											
Osage	77	98.9							12	13	11	11	11	9											
Clinton	32	92.2							1	1	1	1	1	1	2	3	3	3	3	3	3	3	1	b	
Nemaha	64	91.2									1	2	5	10	20	25	30	28	28	28	26	25	22	20	
Cherokee	17	93.9											1	5											
Mindo	41	88.6											1	1	1	1	1	1	1	1	1	b			
Cherokee Res.	33	85.0													10	20	25	26	26	26	25	25	22	22	
Andrew	94	100.0													1	1	2	3	3	4	4	4	5	6	
Mo. 0-205	53	104.0														1	5	10	15	15	15	14	12	10	
Ajax	24	112.4														1	1	1	1	1	1	1	1	1	
Beaver	7	102.0															1	1	1	1	1	2	1	1	
Branch	19	114.9															1	1	1	1	1	2	2	2	
Rodney	10	93.3																		b	b	b	b	b	
Jackson	20	103.0																		1	1	a	a	1	
Clintland	42	86.8																			1	2	1	1	
Bonda	29	96.0																			2	1	1		
Garry	24	103.4																			1	b	b	1	
Newton	41	88.6																				b			
LaSalle	20	91.6																				b			
Benton	26	93.4																				1			
Minhafer	22	97.2																				b	5	8	
Cedar									11	13	11	11	11	9											
Otoe											10	11	11	10	38	20									
Unspecified						10	10	10	10	10	10	10	10	10	10	11	15	9	5	3	3	8	13	13	

[a]Source: References; Oats, Nebraska.
[b]Less than .5 percent.

Table A.33. Relative test yields and acreage distribution of oats varieties, North Dakota, 1940 to 1961[a]

	Northern Plains Test Yields		Estimated Percentage of Acreage Planted to Specified Varieties																						
Variety	No. of Tests	% of Andrew	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Richland	44	95.9		6	6	5	5	5	4	4	2			1											
Victory	19	86.8		25	23	22	20	18	17	15	12	10	8	6	5	5	4	3	3	2	2	2			
Gopher	92	93.3		30	29	28	28	27	26	25	22	18	14	10	10	9	9	9	8	8	8	7	5	3	
Rainbow	26	101.1		5	5	5	5	5	5	5	5	5	4	4	4	3	3	3	2	2	2	1	1	1	
Tama	51	96.6								2	2	2	2	1	1	1	1	1	1	1					
Vicland	26	95.8								8	8	8	7	6	5	5	4	3	3	2	2	1			
Marion	46	95.2								4	6	8	9	10	10	10	10	9	9	8	6	5	4	2	
Ajax	24	112.4								2	4	5	10	14	15	15	16	17	17	18	16	15	18	20	
Clinton	41	92.2									1	2	2	3	3	2	2	2	2	2	2	1	1	1	
Benton	26	93.4										1	1	1	1	1	1	1	1	1					
Beaver	7	102.0										1	2	2	2	2	2	2	1	1	1	1	1	1	
Mindo	41	88.6												1	1	1	1								
Bonda	29	96.0												1	1	1	1	1	1	1					
Andrew	94	100.0													2	3	5	7	8	10	12	13	14	15	
Nemaha	26	90.8															1								
Cherokee	22	90.3															1	1	1	1					
Branch	19	114.9															1	2	3	4	4	3	2	2	
Mo. 0-205	62	105.5																		1					
Rodney	10	93.3																		1	4	8	12	15	
Garry	24	103.4																		4	8	12	16	20	
Sauk	15	103.9																				1	1	1	
Burnett	29	106.7																				1	1	1	
Simcoe	42	107.1																				1	1	1	
Minhafer	37	97.2																						1	
Vanguard										2	2	3	3	3	3	3	3	3	2	2	2	2			
Exeter										1	2	2	2	2	2	3	3	3	2	2	2	2	1		
Fortune															b	1	1	1	1	1	1	1			
Ransom																					b	1	1	1	
Unspecified				34	37	40	42	45	48	32	34	35	36	35	35	35	31	32	35	28	28	22	21	15	

[a]Source: References; Oats, North Dakota.

[b]Less than .5 percent.

Table A.34. Relative test yields and acreage distribution of oats varieties, Ohio, 1942 to 1961[a]

Variety	Corn Belt Test Yields: No. of Tests	Corn Belt Test Yields: % of Andrew	Estimated Percentage of Acreage Planted to Specified Varieties: 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Gopher	98	82.6				10	6	2																	
Vicland	30	81.0				5	10	20	25	28	30	5	1												
Marion	49	90.7				29	38	39	33	22	12	8	3												
Columbia	84	91.7				26	23	20	15	12	9	6	2												
Boone	22	80.7					3	8	10	12	15	1													
Tama	56	78.4						1	4	8	10	1													
Clinton 59	79	90.3						2	8	12	16	52	60	60	62	65	65	60	58	25	22	20	19	15	10
Clinton	42	95.1						1	4	6	8	26	30	30	28	25	18	18	16	10	10	10	15	8	5
Ajax	21	123.3										1	4	7	9	8	8	5	5	2	2	1	1	1	1
Nemaha	67	92.8												3	1	1	1	1	b	b	b	b	b		
Mo. 0-205	58	101.4														1	5	8	5	3	1	b	b		
Cherokee	20	90.5															1	1	1	b	b	b	b		
Andrew	102	100.0															2	5	3	1	1	b	1	b	b
Clintland	47	98.2																2	10	55	58	60	54	65	45
Clarion	25	99.1																	1	2	2	2	2	2	2
Garry	25	103.7																	b	1	2	1	1	1	1
Bentland	14	93.2																		b	1	1	b		
Putnam	27	93.6																			b	b	b		
Rodney	12	84.0																				b	1	1	1
Newton	46	96.8																				1	2	2	2
Minhafer	33	104.8																				1	b	b	b
Goodfield	21	95.9																						1	7
Clintland 60	27	102.3																						2	25
Iowar						10	8	2																	
Vanguard						10	5	2	1																
Unspecified						10	7	3	0	0	0	0	0	0	0	0	0	0	1	1	1	3	4	2	1

[a]Source: References; Oats, Ohio.

[b]Less than .5 percent.

Table A.35. Relative test yields and acreage distribution of oats varieties, Oklahoma, 1940 to 1961[a]

Variety	Oklahoma Test Yields: No. of Tests	W.-Sp. Index	Comb. Index	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
				Estimated Percentage of Acreage Planted to Specified Varieties																					
W. Fulghum	17	106.8	106.8	10	10	10	5	5	1																
Lee	21	79.2	79.2	20	20	19	18	6	4	5															
Wintook	98	100.0	100.0			1	2	4	6	8	10	10	10	10	8	8	12	15	8	3	1	1	1	1	1
Tennex	101	105.7	105.7			1	5	5	10	10	10	12	12	12	12	10	10	5	2	1	1	1	1	1	1
Fultex	11	96.6	96.6				3	3	3	1	1														
Fulwin	14	100.0	100.0						1	1															
Forkedeer	78	105.3	105.3						2	6	10	10	12	13	15	15	18	19	18	20	17	17	17	15	15
Traveler	72	102.3	102.3							3	5	8	6	6	5	5	4	2							
Stanton Sel.	76	103.3	103.3								1	3	5	5	5	5	4	2							
De Soto	23	110.2	110.2								2	3	3	4	5	5		2	2	2	2				
Arkwin	9	107.8	107.8														3	8	28	43	38	35	30	26	20
Mustang	20	108.8	108.8															8	8	5	2	2	b	b	b
Cimarron	68	104.0	104.0																5	15	30	35	40	45	50
Bronco	10	115.9	115.9																			2	3	4	5
Nortex	40	105.7	71.8	8	8	5	5	5	4	3															
Red Rustproof	27	98.8	67.1	50	50	50	40	40	35	29	30	21	15	15	12	10	5	2							
New Nortex	13	96.9	65.8	2	2	4	5	10	5	5	4	3	2	1	1	1	1	3	3	1	1	1	1	1	1
Fultex	10	100.8	68.4				2	2	2																
Kanota	105	100.0	67.9				5	10	20	22	22	24	25	20	20	17	17	12	10	3	3	2	1	1	1
Andrew	66	118.7	80.6									1	3	5	8	13	14	15	5	3	2	1	1	1	1
Clinton	7	75.9	51.5										1	2	2	1	1	1	1						
Nemaha	62	103.1	70.0												1	2	2								
Cherokee Res.	10	84.7	57.5														3	2	2						
Mo. 0-205	6	124.1	84.3															3	5	3	2	1	1	1	1
Neosho	14	93.6	63.6																1						
Cherokee													1	2	2	3	1								
Clintland																			1						
Dubois																						b	b	b	b
Victor Grain 48-93																						1	1	1	1
Unspecified				10	10	10	10	10	7	7	5	5	5	5	4	5	5	1	1	1	1	1	3	3	3

[a]Source: References; Oats, Oklahoma.

[b]Less than .5 percent.

Table A.36. Relative test yields and acreage distribution of oats varieties, South Dakota, 1942 to 1961[a]

Variety	Northern Plains Test Yields No. of Tests	Northern Plains Test Yields % of Andrew	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Anthony	19	96.6				10																			
Iogold	12	89.5				20	20																		
Gopher	92	93.3				50	40	30	20	20	10														
Boone	16	90.4					10	20	10	10	10	10	5												
Tama	51	96.6					10	10	20	30	40	40	20	10	10	5									
Marion	46	95.2							5	5	5	10	20	20	10	10	10	5							
Bonda	29	96.0									5	10	10	20	10	10	10	10	5						
Clinton	41	92.2									5	10	20	30	30	30	30	20	20	10	10				
Andrew	94	100.0											5	10	10	10	20	20	20	20	10	10	10	10	10
Bonham	14	95.1														10	10	10	10						
Cherokee	22	90.3														5	10	10	10	10	10	10	5	5	5
Mo. 0-205	62	105.5																10	15	30	30	20	20	10	10
Branch	19	114.9																5	10	10	20	10	5	5	5
Garry	24	103.4																		5	5	10	10	10	10
Waubay	30	94.2																			5	5			
Rodney	10	93.3																				5	5	5	5
Minhafer	37	97.2																				5	10	20	20
Burnett	29	106.7																				5	10	10	10
Clintland 60	25	93.3																					10	10	10
Unspecified						20	20	40	45	35	25	20	20	10	30	20	10	10	10	15	10	20	15	15	15

[a]Source: References; Oats, South Dakota.

Table A.37. Relative test yields and acreage distribution of oats varieties, Texas, 1939 to 1961[a]

Variety	Texas Test Yields No. of Tests	Texas Test Yields % of New Nortex	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Nortex	55	93.5	55	55	50	30	29	10	5	1															
Texas Red Rusp.	38	97.6	35	35	30	39	39	46	40	40	38	30	30	30	30	20	19	10	10	7	5	5	5	5	3
New Nortex	151	100.0	10	10	20	30	30	40	49	55	60	69	69	69	69	70	68	72	60	44	35	30	42	35	32
Ranger	52	94.6				1	2	4	6	4	2	1	1	1											
Mustang	77	103.8													1	5	5	10	20	28	30	34	20	15	14
Victorgrain	73	96.0														5	5	5	5	10	10	5	10	5	5
Nortex 107	61	95.6															3	3	3	3	5	5	8	9	7
Alamo	64	96.5																	1	3	5	10	5	5	3
Bronco	61	97.5																	1	5	10	10	5	5	5
Taggert	6	61.8																					1	1	2
More Grain	6	122.0																					1	10	19
Suregrain																						1	3	10	10
Unspecified			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[a]Source: References; Oats, Texas.

Table A.38. Relative test yields and acreage distribution of oats varieties, Wisconsin, 1939 to 1961[a]

Variety	Lake States Test Yields: No. of Tests	Lake States Test Yields: % of Andrew	Estimated Percentage of Acreage Planted to Specified Varieties: 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Gopher	42	81.5	5	5	5	5																			
Forward	11	58.7	8	8	8	8	4	1																	
Spooner	14	63.6	8	8	8	8	4	1																	
States Pride	12	77.4	50	50	50	50	25	5																	
Vicland	15	79.0				3	55	85	93	89	80	60	19	12	10	5									
Forvic	14	85.5									5	5													
Clinton	18	89.9									2	15	47	49	50	46	42	42	18	9	7	4	2		
Ajax	13	109.2									1	6	7	8	8	8	9	10	11	11	8	8	7	6	7
Bonda	24	95.7										3	9	12	20	24	25	26	16	9	5	3	2		
Mindo	18	84.0												3	5	5									
Branch	13	92.4													2	8	10	20	26	21	22	14	10	9	7
Nemaha	9	84.0																	7	7	3	3	2		
Clintland	10	96.3																	4	13	11	12	13	11	7
Rodney	5	110.5																	1	4	6	6	5	5	5
Sauk	8	110.3																	5	16	24	20	19	14	11
Beedee	10	104.1																		1	4	17	24	27	32
Fayette	8	87.8																			2	5	3		
Garry	10	117.4																			3	4	5	6	6
Minhafer	17	105.4																					4	6	3
Goodfield	9	94.0																						1	5
Burnett	13	109.1																						1	2
Swedish Select			5	5	5	5	2																		
Wisc. Wonder			8	8	8	8	4	1																	
Portage																									3
Unspecified			16	16	16	13	6	7	7	11	12	11	18	16	5	4	14	2	12	9	5	4	4	14	12

[a]Source: References; Oats, Wisconsin.

Table A.39. Relative test yields and acreage distribution of soybeans varieties, Arkansas, 1943 to 1960[a]

	Delta States Test Yields		Estimated Percentage of Acreage Planted to Specified Varieties																						
Variety	No. of Tests	% of Ogden	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Perry	68	85																2	2	2					
S-100	77	85											5	8	10	10	10								
Dortchsoy 67	46	92															5	10	10	8	5	3	4	2	
Dorman	82	87																10	10	12	10	10	8	3	
Arksoy	63	73					30	30	25	25	20	20	15	10	5	5	3								
Ogden	122	100					20	25	35	35	40	45	45	50	55	60	60	50	45	30	25	20	18	9	
Lee	66	105																15	20	35	50	60	60	68	
Hood	53	108																						6	
Tokyo	4	60					5																		
Volstate	49	86					10	10	15	10	5	5	5	5	2										
Roanoke	70	89								5	10	10	10	10	10	10	5	5	5	5	2				
Jackson	40	88																		3	3	4	6	8	
Tanner							5	5	5	5	5														
Loredo							15	15	10	5	5	5	5	5	3	2	2								
Unspecified							15	15	10	15	15	15	15	12	15	13	15	8	8	5	5	3	4	4	

[a]Source: References; Soybeans, Arkansas.

Table A.40. Relative test yields and acreage distribution of soybeans varieties, Illinois, 1941 to 1960[a]

Variety	Corn Belt Test Yields No. of Tests	Corn Belt Test Yields % of Richland	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Blackhawk	186	103													1	1	1	1	1	2	2	1	2	1	
Chippewa	186	105																				1	1	1	
Mukden	129	104			1	1	1	2	1				1												
Richland	348	100			5	7	8	12	12	9	7	5	4	2	2	1	1								
Hawkeye	369	113										2	13	29	36	33	37	37	43	39	39	32	26	23	
Adams	313	116												2	2	6	9	14	12	15	14	12	11	6	
Harosoy	232	117																2	4	11	25	29	33	35	
Dunfield	327	92			14	13	11	5	4	3															
Illini	312	95			58	58	53	53	44	16	5	3	2	2	2	1	1	1							
Lincoln	349	107						1	10	50	66	68	54	41	32	27	26	20	17	11	6	4	2	2	
Shelby	181	117																					1	7	
Chief	252	99			11	11	11	11	11	10	8	12	10	7	6	4	4	3	2	2	1				
Macoupin	49	88						1	2	2	1	2	2	2											
Wabash	217	101											2	4	9	9	6	7	6	4	1	1	1		
Perry	140	106															1	2	1	1				1	
Clark	135	115																2	7	13	10	17	22	22	
Morse								1	2																
Virginia								2	2	2	1														
Kingwa									1																
Earlyana										1															
Bavender																1									
Unspecified					11	10	16	12	11	7	12	8	12	11	10	17	14	11	7	2	2	3	1	2	

[a]Source: References; Soybeans, Illinois.

Table A.41. Relative test yields and acreage distribution of soybeans varieties, Indiana, 1941 to 1960[a]

Variety	Corn Belt Test Yields No. of Tests	Corn Belt Test Yields % of Richland	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Earlyana	182	97					1	2	3	3	3	5	5	2	2	1									
Blackhawk	186	103														1	2	3	2	1	3	3	2	1	
Harosoy	232	117																2	12	17	31	35	40	39	
Mukden	129	104			3	3	4	2	1	1															
Richland	348	100			16	22	25	29	33	34	35	35	25	23	15	10	3								
Lincoln	349	107						1	7	12	20	25	32	36	42	42	42	39	30	30	10	11	8	4	
Hawkeye	369	113										1	10	21	27	30	38	37	28	23	43	34	27	24	
Adams	313	116																					1		
Lindarin	121	115																					1	3	
Illini	312	95			10	10	11	5	3	2	2	1													
Chief	252	99			6	5	5	5	4	1	1	1													
Dunfield	327	92			45	42	40	40	33	30	22	16	14	3											
Shelby	181	117																					1	8	
Gibson	143	92					1	3	4	4	4	4	4	4	3	2	1								
Patoka	172	96					1	3	4	5	5	5	4	5	3	2	1								
Wabash	217	101												1	5	9	9	11	4	4	1				
Perry	140	106															1	4	2						
Clark	135	115																1	20	23	8	14	17	18	
Unspecified					20	18	12	10	8	8	8	7	6	5	3	3	3	3	2	2	4	3	3	3	

[a]Source: References; Soybeans, Indiana.

Table A.42. Relative test yields and acreage distribution of soybeans varieties, Iowa, 1939 to 1960[a]

	Corn Belt Test Yields		Estimated Percentage of Acreage Planted to Specified Varieties																						
Variety	No. of Tests	% of Richland	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Wis. Manch 3	61	97	10	10	8	7	3																		
Habaro	123	96			3	3	4	6	5	3	2	1	1												
Earlyana	182	97					2	8	14	7	8	5	3												
Blackhawk	186	103														10	12	13	14	23	18	18	7	3	
Chippewa	186	105																			3	11	18	20	
Mukdew	129	104	45	44	42	40	37	23	17	15	9	7	4												
Richland	348	100		1	3	5	10	20	28	25	16	14	10												
Hawkeye	369	113											16	45	50	53	49	61	60	50	58	54	59	60	
Adams	313	116												3	18	18	17	12	10	10	9	8	4	2	
Harosoy	232	117																				3	6	6	
Dunfield	327	92	10	10	10	10	10	11	10	4	1	2	1												
Illini	312	95	35	35	33	30	28	26	22	15	2	2	1												
Lincoln	349	107							3	30	62	65	60	45	25	15	11	6	7	4	3	2	2	1	
Clark	160	126																	3	5	6	3	3	4	
Ford	95	111																						4	
Unspecified			0	0	1	5	6	6	1	1	0	4	4	7	7	4	11	8	6	8	3	1	1	0	

[a]Source: References; Soybeans, Iowa.

Table A.43. Relative test yields and acreage distribution of soybeans varieties, Louisiana, 1942 to 1960[a]

Variety	Delta Test Yields No. of Tests	Delta Test Yields % of Ogden	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Dortchsoy 67	46	92.4											2	3	5	3	2								
Dorman	82	87.0																			2				
Delsoy	16	70.8				1																			
Tokyo	4	60.0				5	1																		
Arksoy	63	73.0				55	55	45	30	25	25	20	15	10	5	3	1								
Ogden	122	100.0				10	20	25	35	40	45	50	55	55	60	63	60	60	55	10	15	15	10	10	
Lee	66	104.9																		50	50	50	70	40	
Volstate	49	85.9				5	8	15	20	20	15	10	5	2	1										
Roanoke	70	88.7										5	10	15	18	20	25	25	15	10	1				
Jackson	40	88.1																	15	25	30	30	10	45	
CNS	37	56.9																						2	
Bienville	11	139.1																					3		
Loreda						5	3	2	1																
Tanner						2																			
Unspecified						17	13	13	14	15	15	15	13	15	11	11	12	15	15	5	2	5	7	3	

[a]Source: References; Soybeans, Louisiana.

Table A.44. Relative test yields and acreage distribution of soybeans varieties, Michigan, 1942 to 1960[a]

Variety	Minnesota Test Yields No. of Tests	Minnesota Test Yields % of Earlyana	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Mandarin Ott.	32	106				61	49	29	5	7	13	3													
Norchief	21	105																					1		
Earlyana	25	100					10	56	90	68	60	13	23												
Blackhawk	23	110												57	82	88	82	74	29	25	15	11	10	10	
Monroe	20	101																	9	5	2				
Chippewa	23	126																		5	20	46	43	43	
Richland	6	91				39	41	15	5																
Hawkeye	8	106										84	77	43	18	12	18	26	40	20	20	10	10	5	
Harosoy	7	118																	13	35	35	30	31	38	
Lincoln										25	27														
Unspecified						0	0	0	0	0	0	0	0	0	0	0	0	0	8	10	8	3	5	4	

[a]Source: References; Soybeans, Michigan.

Table A.45. Relative test yields and acreage distribution of soybeans varieties, Minnesota, 1941 to 1960[a]

Variety	Minnesota Test Yields No. of Tests	Minnesota Test Yields % of Earlyana	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
			Estimated Percentage of Acreage Planted to Specified Varieties																						
Early Manch.	11	103			5	5	5	5	5	5	5	5	5	5	5	2	2								
Mand. Ott.	32	106								5	15	25	25	25	25	20	15	10	10	13	5	5	5	5	
Capital	26	114														8	15	30	30	29	10	5	3	2	
Flambeau	31	99																		2	3	2	1	1	
Norchief	23	105																			5	5	5	5	
Grant	23	116																			3	10	8	5	
Comet	12	97																					5	6	
Local Manch.		97			30	35	45	45	45	45	40	30	30	30	30	27	14								
Habaro	17	97			30	30	30	30	30	25	25	25	25	20	20	15	10								
Earlyana	25	100												3	3	3	3								
Monroe	20	101													5	10	10								
Blackhawk	23	110														5	25	40	40	26	15	8	3	2	
Chippewa	23	126																		4	30	40	60	64	
Richland	6	91			5	5	5	5	5	5															
Hawkeye	8	106													3	5	5		5	5	2	3	1	1	
Harosoy	7	118																5	5	5	7	5	3	3	
Mukden					5																				
Renville																				1	2				
Acme																							1	1	
Unspecified					25	25	15	15	15	15	15	15	15	17	9	5	1	15	10	15	18	17	5	5	

[a]Source: Reference; Soybeans, Minnesota.

Table A.46. Relative test yields and acreage distribution of soybeans varieties, Mississippi, 1943 to 1960[a]

Variety	Delta Test Yields No. of Tests	Delta Test Yields % of Ogden	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Macoupin	14	77					5																		
S-100	77	85											5	5	5	5									
Dorman	82	87															2	20	20	10	5	4	2		
Hill	52	95																						3	
Arksoy	63	73					60	50	25	20	15	10	5	5	5	5	5								
Ogden	122	100					5	20	50	65	75	85	80	80	80	75	65	45	45	4					
Lee	66	105																6	6	75	90	90	90	75	
Hood	53	108																						7	
Volstate	49	86											5	5	5	5	5								
Roanoke	70	89														5	20	25	25	5	1				
Jackson	40	88																		5	2	4	6	15	
Unspecified							30	30	25	15	10	5	5	5	5	5	3	4	4	1	2	2	2	0	

[a]Source: References; Soybeans, Mississippi.

Table A.47. Relative test yields and acreage distribution of soybean varieties, Missouri, 1941 to 1960[a]

Variety	Corn Belt Test Yields No. of Tests	Corn Belt Test Yields % of Richland	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Chippewa	186	105																				1	1	1	
Mukden	129	104			8	5	5	2																	
Richland	348	100			3	5	10	20	28	20	10	3													
Hawkeye	369	113										1	2	3	4	7	8	8	8	5	2	2	2	2	
Harosoy	232	117																	2	5	8	8	8	8	
Dunfield	327	92			10	10	10	8	5	3	1														
Illini	312	95			35	32	30	20	13	6	2														
Lincoln	349	107						1	8	25	40	45	40	23	17	15	13	12	10	5	4	4	3	3	
Adams	128	102																2	2	2	2	2	1	1	
Chief	253	99			10	9	8	8	10	10	12	16	13	10	9	6	4	4	2	1	1	1			
Wabash	217	101											3	7	11	15	12	11	10	5	2	1			
Perry	140	106															3	9	9	4	2	2			
Clark	135	115																	5	25	35	35	40	40	
Scott	28	135[b]																					5	5	
S-100	77	88[b]											4	8	10	10	10	7	5	1	2	1	1	1	
Dorman	82	90[b]																	10	15	14	12	8	8	
Arksoy	63	75[b]			25	25	17	12	3																
Ogden-Sel.	122	103[b]			4	8	15	20	28	28	30	30	33	40	42	42	40	40	30	25	20	20	12	12	
Lee	66	108[b]																	1	2	4	6	6	6	
Hood	53	111[b]																					5	5	
Unspecified					5	6	5	9	5	8	5	5	5	9	7	5	10	7	6	5	4	5	8	8	

[a]Source: References; Soybeans, Missouri.

[b]Adjusted Delta States test yields.

Table A.48. Relative test yields and acreage distribution of soybean varieties, Ohio, 1941 to 1960[a]

Variety	Corn Belt Test Yields No. of Tests	Corn Belt Test Yields % of Richland	Estimated Percentage of Acreage Planted to Specified Varieties 39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Earlyana	182	97					1	4	8	10	11	10	10	7	5	4	1								
Monroe	155	97									1	2	3	5	7	9	10	10	10	7	7	7	6	5	
Blackhawk	186	103																		5	5	5	4	4	
Chippewa	186	105																					1	1	
Richland	348	100			16	22	25	29	33	34	35	35	25	23	15	10	3								
Hawkeye	369	113										1	5	14	19	23	27	25	25	22	19	17	19	13	
Harosoy	232	117																10	30	33	41	43	47	47	
Lindarin	121	115																						5	
Illini	312	95			10	10	11	5	3	2	2	1													
Dunfield	327	92			45	42	40	40	33	30	22	16	14	3											
Lincoln	349	107							1	7	12	20	25	33	37	43	43	40	25	25	20	20	17	13	
Ford	95	111																						1	
Shelby	181	117																						4	
Chief	252	99			6	5	5	5	4	1	1	1													
Patoka	172	96					1	1	2	2	2	2	2	1	1										
Gibson	143	92					1	2	2	2	2	2	2	2	2	1	1								
Clark	135	115																	5	5	5	5	6	6	
Unspecified					23	21	16	14	14	12	12	10	14	12	14	10	15	15	5	3	3	3		0	

[a]Source: References; Soybeans, Ohio.

Table A.49. Relative test yields and acreage distribution of soybean varieties, Wisconsin, 1942 to 1960[a]

Variety	Minnesota Test Yields No. of Tests	Minnesota Test Yields % of Earlyana	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
			Estimated Percentage of Acreage Planted to Specified Varieties																						
Flambeau	31	99							4	9	9	9	9	10	10	14	14	15	15	10	5	5	2		
Mandarin		106													2	4	5	5	2	5	5				
Capital	26	114														2	5	5	8	5	5	5			
Norchief	23	105																		7	15	15	10	5	
Grant	23	116																			2	5	10	10	
Habaro	17	97				4	4	4	4	5	5	5	5	5	5	4	3								
Com. Manchu		97				70	70	73	68	66	66	66	64	58	38	38	27	25	12		3				
Earlyana	25	100						4	4	5	5	5	5	5	5	4	2								
Monroe	20	101												5	10	9	10	10	10	10	5				
Blackhawk	23	110												5	15	14	19	25	40	30	20	15	10	10	
Chippewa	23	126																		18	35	40	50	55	
Richland	6	91				4	4	4	4	5	5	5	5	5	5										
Hawkeye	8	106													5	4	10	10	10	5	5	5	3	3	
Harosoy	7	118																	1	1			10	12	
Illini						4	4	4	4	5	5	2	2												
Mandarin 507						13	13	9	9	5	5	5	5	2											
Lincoln												3	5	5	5	4	5	5	2	2					
Unspecified						5	5	2	3	0	0	0	0	0	0	3	0	0	0	7	0	10	5	5	

[a]Source: References; Soybeans, Wisconsin.

Table A.50. Relative test yields and acreage distribution of wheat varieties, Alabama, at five year intervals, 1939 to 1959[a]

Variety	Southeast Test Yields No. of Tests	 % of Chancellor	Estimated Percentage of Acreage Planted to Specified Varieties 39	 44	 49	 54	 59
Purplestraw	95	79.6	77.5	80.3	7.6	4.5	.5
RedHart	31	85.3		.1	8.8		
Sanford	31	93.7		9.8	44.8	16.5	2.5
Carala	25	89.0			6.7		
Chancellor	95	100.0			1.2	22.8	.2
Coker 47-27	76	105.5				23.1	40.6
Coastal	68	105.5				3.8	15.6
Anderson	81	109.4				3.9	29.0
Others			22.5	9.8	30.9	25.4	11.6

[a]Source: References; Wheat, Alabama.

Table A.51. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Georgia, 1939 to 1959[a]

Variety	Southeast Test Yields No. of Tests	Southeast Test Yields % of Chancellor	Estimated Percentage of Acreage Planted to Specified Varieties 39	44	49	54	59
Purplestraw	95	79.6	71.9	49.4	5.5	5.0	3.6
Redhart	31	85.3	21.3	33.1	15.2	1.9	1.3
Sanford	31	93.7		12.9	72.0	13.4	3.3
Chancellor	95	100.0			1.7	52.1	15.1
Atlas	76	102.5				1.1	2.9
Coastal	68	105.5				5.7	5.1
Coker 47-27	76	105.5				15.0	13.2
Anderson	81	109.4				1.4	15.1
Bledsoe	38	107.9					23.2
Taylor	79	108.9					2.1
Other			6.8	4.6	5.6	4.4	15.1

[a]Source: References; Wheat, Georgia.

Table A.52. Relative test yields and acreage distribution of wheat varieties, of selected years, Illinois, 1929 to 1961[a]

Variety	Illinois Test Yields No. of Tests	Illinois Test Yields % of Turkey	Estimated Percentage of Acreage Planted to Specified Varieties 29	34	39	44	49	50	51	52	53	54	55	56	57	58	59	60	61
Turkey	24	100.0	36	28	17	11	4	2	0	1	1	1							
Kanred	4	99.7	2	1	1														
Michikof	10	87.1	2	1	3	1													
Iobred	10	99.9			4	1													
Purkof	24	96.2	2	5	8	3	2	0	0	0	0	0	1						
Brill	28	101.9				2	2	2	1										
Cheyenne	14	101.9			2	2													
Pawnee	9	114.4					32	36	35	44	43	46	49	48	43	39	44	38	44
Westar	5	123.2								1	3	4	3	3	3	1	1		
Ponca											2	2	2	2	6	3	6	7	6
Poole	12	86.4	2	2	0	1													
Mediterranean	2	76.0	2	3	1	4													
Red May	10	73.8	6	4	2	2	2	1											
Fultz	4	93.0	20	26	18	19	7	5	2	0	1	2	1						
Fulcaster	36	96.0	6	3	8	10	5	4	2	2	1	1	1						
Fulhio	24	88.3	3	10	19	17	5	3	1	1	1	1		1					
Kawvale	17	108.3			1	4	5	3	2	1	1								
Clarkan	20	97.1				2	3	2	1	1	1								
Thorne	11	79.6				5	13	9	10	4	5	4	4	4	2	1	1	1	1
Royal	18	102.9					4	17	21	20	18	14	11	5	2	1			
Vigo	13	104.9					1	5	12	15	13	11	11	6	2	0	1		
Seneca	4	107.6								1	2	3	4	6	4	3	4	2	2
Saline	11	116.0									3	5	5	4	1	0	1		
Knox	17[b]	109.1											2	13	24	30	23	25	16
Dual	46[b]	105.4												1	4	11	6	5	3
Vermillion	39[b]	112.5													1	3	7	15	18
Other			19	17	16	16	15	11	13	9	5	6	6	7	8	8	6	7	10

[a]Source: References; Wheat, Illinois.

[b]Adjusted Corn Belt test yields.

Table A.53. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Indiana, 1939 to 1959[a]

Variety	Corn Belt Test Yields No. of Tests	% of Trumbull	Estimated Percentage of Acreage Planted to Specified Varieties 39	44	49	54	59
Trumbull	135	100.0	9.6	11.1	2.6	.8	
Fulcaster	58	103.3	.9	.4	1.0		.1
Purkof	69	108.6	11.2	8.9	1.0	.3	
Thorne	75	105.5		5.1	18.0	10.2	2.2
Fairfield	68	109.2		2.8	29.2	6.5	.7
Vigo	19	104.7			20.5	50.4	2.7
Butler	24	117.9			.1	4.0	.3
Seneca	24	106.0				13.0	6.1
Knox	72	110.7				.8	38.6
Vermillion	39	116.6					18.9
Dual	46	124.5					25.6
Others			78.3	71.7	27.6	14.0	4.8

[a]Source: References; Wheat, Indiana.

Table A.54. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Iowa, 1929 to 1959[a]

Variety	Iowa Test Yields No. of Tests	Iowa Test Yields % of Iowin	Estimated Percentage of Acreage Planted to Specified Varieties 29	34	39	44	49	54	59
Iobred	20	94.0	18.0	25.5	27.9	25.4	3.6		
Kanred	10	92.0	9.2	8.3	3.5	1.4	.3	1.0	
Turkey	14	95.4	58.4	52.5	30.1	15.2	4.8	1.3	1.5
Ioturk	29	99.8	1.0	2.6	2.7	.4			.1
Iowin	34	100.0	.2	2.4	21.2	50.3	13.1	15.9	.2
Nebred	5	113.2				.2	1.3	4.5	3.6
Iohardi	9	100.9					.1	3.7	.5
Pawnee	18	103.8					65.7	54.7	71.8
Kiowa	6	105.7						1.4	.2
Marquis	10	42.6	5.0	5.0	1.0		.3		
Thatcher	9	70.4			7.1	3.7	1.5		
Rival	11	69.1					2.0	1.1	
Mida	10	71.0					2.3	3.7	
Henry	14	85.0					2.9	8.2	.7
Selkirk	7	98.9							5.9
Rushmore	10	77.3						.3	.9
Ponca								.2	2.5
Wichita									4.1
Others			8.2	3.7	6.5	3.4	2.1	4.0	8.0

[a]Source: References; Wheat, Iowa.

Table A.55. Relative test yields and acreage distribution of wheat varieties, Kansas, at five year intervals, 1929 to 1959[a]

Variety	Kansas Test Yields No. of Tests	% of Kharkof	Estimated Percentage of Acreage Planted to Specified Varieties 29	34	39	44	49	54	59
Kanred	49	104	12.0	10.4	4.5	2.7	.2	b	b
Turkey	87	101	48.0	44.3	28.9	14.7	1.7	.3	.3
Blackhull	60	108	33.4	34.9	31.0	15.5	3.6	.5	.2
Early Black	63	113	b	.6	1.6	9.0	4.6	.5	
Tenmarq	72	115		1.3	19.6	36.6	8.5	2.2	1.2
Kawvale	17	120		.3	6.4	4.4	.7	.1	
Chiefkan	41	120			2.8	8.6	1.3	.5	b
Red Chief	53	109				4.4	3.9	6.1	.2
Pawnee	71	119				b	36.0	29.0	11.2
Triumph	37	118				.1	6.4	7.4	14.8
Comanche	73	120				.1	20.8	11.1	8.9
Blue Jacket	23	114					.7	3.3	b
Witchita	64	117					9.4	24.3	22.7
Ponca	43	116						2.4	11.6
Kiowa	44	120						8.1	13.8
Bison	21	117							9.8
Concho	22	133							2.0
Others			6.6	8.2	5.2	3.9	2.2	4.2	3.3

[a]Source: References; Wheat, Kansas.

[b]Less than .5 percent.

Table A.56. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Michigan, 1939 to 1959[a]

Variety	Michigan Test Yields No. of Tests	% of Trumbull	Estimated Percentage of Acreage Planted to Specified Varieties 39	44	49	54	59
Fulcaster	10	93.2	1.7	.2			
Trumbull	21	100.0	2.1	.3	.2	.1	
Red Rock	10	101.0	16.0	14.4	1.1	.2	
Bald Rock	10	100.2	13.2	8.6	.8	.2	.1
Thorne	13	102.9		3.2	4.9	5.9	2.3
Yorkwin	13	106.5		11.8	67.9	65.1	13.9
Vigo	3	99.8			.4	2.8	.2
Cornell 595	5	108.3			5.1	9.9	6.0
Seneca	4	107.0				4.8	5.4
Genesee	10	125.4				2.3	63.0
Dual	6	118.4					3.6
Others			67.0	61.5	19.6	8.7	5.5

[a]Source: References; Wheat, Michigan.

Table A.57. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Minnesota, 1929 to 1959[a]

Variety	Minnesota Test Yields: No. of Tests	Minnesota Test Yields: % of Thatcher	Estimated Percentage of Acreage Planted to Specified Varieties: 29	34	39	44	49	54	59
Kubanka	30	86.0	3.6	.3	.3				
Marquillo	20	73.0	.8	8.1	7.1	1.0	.1		
Ceres	56	86.8	1.5	21.3	3.0	.2	.1		
Marquis	56	72.3	59.3	44.3	1.5	.1	.3	.1	
Mindum	114	104.5	13.8	8.1	5.8	4.8	1.5	1.7	
Renown	31	104.8			.3	4.8	.7	.1	
Thatcher	154	100.0			71.6	16.8	1.8	1.9	.2
Regent	36	104.9				21.3	8.1	.1	
Rival	75	110.7				31.5	27.5	1.8	
Premier	12	115.2				.1	3.0	.2	
Pilot	65	108.5				6.1	.5	.1	.1
Carleton	47	101.6					6.2	.2	
Redman	17	105.7					4.4	.8	
Mida	77	113.0					32.7	2.2	
Rushmore	32	119.0						14.5	.1
Langdon	18	132.0							1.8
Lee	67	121.3						66.0	.5
Selkirk	39	141.2						.6	91.1
Others			21.0	17.9	10.4	13.3	13.1	9.7	6.2

[a]Source: References; Wheat, Minnesota.

Table A.58. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Montana, 1929 to 1959[a]

Variety	Montana Test Yields No. of Tests		Estimated Percentage of Acreage Planted to Specified Varieties 29	34	39	44	49	54	59
		% of Thatcher							
Supreme	49	100	6.8	5.4	2.7	.9	.9	.5	
Marquis	43	90	72.8	66.7	55.6	28.4	12.3	4.1	1.1
Ceres	85	100	.4	4.4	16.0	13.3	15.6	11.9	5.7
Thatcher	86	100			2.2	22.5	24.9	32.8	18.0
Pilot	73	96				2.9	1.6	1.8	.2
Rescue	59	93					11.7	9.7	10.4
Chinook	42	98						.1	5.4
Lee	53	99						1.3	2.5
Selkirk	38	99							2.5
Centana	44	103							6.5
		% of Kharkof							
Turkey	11	100	12.5	16.1	16.3	18.9	6.9	3.7	1.8
Newturk	36	101	.3	.6	1.2	1.4	1.3	1.1	1.9
Karmont	43	103	1.7	2.6	2.8	4.4	8.6	7.0	9.0
Yogo	43	109			.5	3.1	9.4	17.9	10.8
Cheyenne	11	107						.1	17.8
Others			5.5	4.2	2.7	4.2	6.8	8.0	6.4

[a]Source: References; Wheat, Montana.

Table A.59. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Nebraska, 1929 to 1959[a]

Variety	Nebraska Test Yields No. of Tests		Estimated Percentage of Acreage Planted to Specified Varieties 29	34	39	44	49	54	59
		% of Turkey							
Kanred	21	98	13.5	8.7	2.4	.8	.3	.2	
Blackhull	45	99	.6	1.2	6.2	4.8	1.7	.2	
Nebraska 60	41	99	8.9	18.9	10.1	4.8	.7	.5	.2
Turkey	33	100	68.2	59.5	58.0	43.4	7.8	2.7	.1
Cheyenne	68	110		1.2	14.8	22.7	25.2	27.5	28.9
Tenmarq	60	100			.2	2.8	1.4	.5	.2
Nebred	68	108			.2	15.3	26.1	26.6	25.1
Pawnee	58	113				.3	33.4	35.7	31.0
Wichita	29	102					.2	1.5	1.4
Ponca	23	105						.2	2.4
Bison	13	113							7.1
		% of Thatcher							
Marquis	57	75	3.9	2.8	.8	.2			
Java	55	113		.2	.4	.1			
Ceres	47	92		2.9	1.6	.8	.2		
Komar	13	105			.1	.2			
Thatcher	57	100			.3	.9	.3		
Mida	29	108					.7	.7	.1
Rival	36	104						.1	
Rushmore	22	113						.2	
Others			4.9	4.6	4.9	2.9	2.0	3.4	3.4

[a]Source: References; Wheat, Nebraska.

Table A.60. Relative test yields and acreage distribution of wheat varieties, at five year intervals, North Dakota, 1929 to 1959[a]

Variety	North Dakota Test Yields No. of Tests	% of Thatcher	Estimated Percentage of Acreage Planted to Specified Varieties 29	34	39	44	49	54	59
Marquis	76	83	52.6	39.4	3.0	.1	.2	.3	
Kubanka	36	108	23.1	12.4	10.1	3.2	2.4	.7	
Ceres	89	91	3.0	34.0	20.3	2.7	.6		.1
Mindum	135	104	10.1	7.4	16.6	12.4	8.1	12.9	.5
Renown	29	94			.6	4.5	.1		
Thatcher	153	100			41.6	26.4	13.9	10.9	2.0
Regent	24	101				9.8	2.3	.6	
Carleton	12	106				.2	4.5	.3	
Stewart	49	112				.4	10.6	2.6	
Rival	96	106				25.8	10.0	4.3	.1
Mida	120	106				.2	31.9	13.9	1.7
Pilot	63	107				7.0	1.8	.9	.2
Cadet	36	103					5.1	2.9	.1
Rescue	40	93					2.0	2.6	.4
Rushmore	56	102						10.4	2.0
Lee	80	108						31.7	13.0
Selkirk	48	120						.1	57.1
Conley									5.8
Others			11.2	6.8	7.8	7.3	6.5	4.9	17.0

[a]Source: References; Wheat, North Dakota.

Table A.61. Relative test yields and acreage distribution of wheat varieties, at five year intervals, North Carolina, 1939 to 1959[a]

Variety	Appalachian Test Yields No. of Tests	Appalachian Test Yields % of Trumbull	Estimated Percentage of Acreage Planted to Specified Varieties 39	44	49	54	59
Redhart	32	87.5	28.9	54.6	54.4	9.3	3.4
Purplestraw	68	90.0	13.6	6.4	5.2	1.5	.3
Forward	16	92.0	5.0	5.3	7.2	1.9	.5
Fulcaster	30	97.3	17.7	5.2	5.6	1.3	.7
Leap	61	98.5	17.4	10.8	5.0	1.9	.4
Atlas 66	49	111.1			.3	30.9	22.3
Thorne	44	112.1			1.4	17.4	13.1
Atlas 50	37	115.2			.4	20.4	3.2
Coker 47-27	49	116.5				4.5	5.5
Seneca	13	120.3				.1	1.9
Taylor	52	120.5				.1	2.0
Anderson	52	121.0				2.9	31.1
Knox	66	109.3					8.7
Others			17.4	17.7	20.5	7.8	6.9

[a]Source: References; Wheat, North Carolina.

Table A.62. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Ohio, 1939 to 1959[a]

Variety	Corn Belt Test Yields: No. of Tests	Corn Belt Test Yields: % of Trumbull	Estimated Percentage of Acreage Planted to Specified Varieties: 39	44	49	54	59
Trumbull	135	100.0	54.0	20.8	10.3	2.5	.2
Thorne	75	105.5	.1	56.0	63.3	23.9	10.3
Vigo	19	104.7			1.6	12.1	2.8
Fairfield	68	109.2			2.9	.5	.1
Butler	24	117.9			2.1	17.0	5.4
Seneca	24	106.0				33.7	48.9
Knox	72	110.7					12.0
Vermillion	39	116.6					7.1
Dual	46	124.5					6.6
Others			45.9	23.2	19.8	10.3	6.6

[a]Source: References; Wheat, Ohio.

Table A.63. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Oklahoma, 1929 to 1959[a]

Variety	Oklahoma Test Yields: No. of Tests	Oklahoma Test Yields: % of Kharkof	Estimated Percentage of Acreage Planted to Specified Varieties: 29	34	39	44	49	54	59
Kanred	40	98	7.5	5.0	2.5	.7	.1	.1	
Turkey	43	97	47.4	44.9	29.3	15.0	1.6	.6	.3
Blackhull	53	103	34.2	32.0	36.6	16.9	1.9	.3	.2
Tenmarq	83	102			10.0	40.3	3.6	1.7	1.1
Early Black	97	106			1.9	7.0	6.1	.7	
Chiefkan	33	108			1.5	5.9	.8	.1	
Red Chief	56	113				3.5	5.0	5.0	.1
Triumph	55	120				1.3	41.5	40.5	59.0
Blue Jacket	14	107					.2	2.7	
Pawnee	74	119					18.9	4.8	.9
Comanche	74	122					11.0	9.6	3.5
Wichita	63	122					4.9	19.0	21.0
Kiowa	21	107						.4	1.2
Ponca	41	117						2.3	.7
Concho	32	143							8.2
Others			10.9	18.1	18.2	9.4	4.4	12.2	3.8

[a]Source: References; Wheat, Oklahoma.

Table A.64. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Pennsylvania, 1939 to 1959[a]

Variety	Northeastern Test Yields No. of Tests	Northeastern Test Yields % of Trumbull	Estimated Percentage of Acreage Planted to Specified Varieties 39	44	49	54	59
Leap	3	95.4	25.1	20.8	1.1	.1	
Forward	4	101.4	19.0	14.7	2.5	.3	
Fulcaster	16	86.6	3.4	2.7	1.8	.3	.1
Nittany	13	105.5	41.9	35.2	3.7	1.0	.2
Yorkwin	28	111.9	.1	1.8	1.1	.4	.1
Trumbull	75	100.0		.2	.3	.6	
Nured	10	118.2		.3	.7	.1	
Thorne	28	111.0		19.7	73.9	60.2	23.6
Cornell 595	16	128.4			1.4	1.4	.3
Butler	15	103.6				1.3	.2
Pennoll	17	109.9				19.7	47.6
Seneca	15	117.6				7.1	9.9
Genesee	55	123.7				.2	.4
Dual	30	120.6					10.9
Others			10.5	4.6	13.5	7.3	6.7

[a]Source: References; Wheat, Pennsylvania.

Table A.65. Relative test yields and acreage distribution of wheat varieties, at five year intervals, South Carolina, 1939 to 1959[a]

Variety	Southeast Test Yields No. of Tests	Southeast Test Yields % of Chancellor	Estimated Percentage of Acreage Planted to Specified Varieties 39	44	49	54	59
Purplestraw	95	79.6	29.1	26.8	5.5	3.1	.4
Redhart	31	85.3	47.5	49.8	60.6	12.4	1.9
Hardired	31	100.6		7.8	18.0		
Carala	25	89.0			1.0	.3	
Sanford	31	93.7			2.5	.5	.1
Chancellor	95	100.0			2.2	19.9	.3
Atlas 50	54	103.1				11.9	
Atlas 66	76	102.5				7.5	6.5
Coastal	68	105.5				7.0	2.6
Coker 47-27	76	105.5				16.9	10.2
Taylor	79	108.9				.5	9.7
Anderson	81	109.4				13.8	61.3
Others			23.4	15.6	10.2	6.2	7.0

[a]Source: References; Wheat, South Carolina.

Table A.66. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Tennessee, 1939 to 1959[a]

Variety	Appalachian Test Yields No. of Tests	% of Trumbull	Estimated Percentage of Acreage Planted to Specified Varieties 39	44	49	54	59
Mediterranean	2	70.2	1.9	3.5	1.2	.1	
Forward	16	92.0	6.1	5.7	2.4	.3	
Purplestraw	68	90.0	1.5	3.5	7.5	5.6	1.4
Currell	2	91.1	13.6	16.2	5.3	.9	.1
Fulcaster	30	97.3	43.0	34.0	24.1	11.0	8.7
Redhart	32	87.5		2.0	6.3	1.4	
Thorne	44	112.1		.1	7.6	19.5	11.8
Carala	27	97.5			3.7		
Vigo	12	104.5				30.7	17.4
Coker 47-27	49	116.5				.4	1.5
Seneca	13	120.3				.5	16.1
Anderson	52	121.0				2.7	4.1
Knox	66	109.3					16.3
Others			33.9	35.0	41.9	26.9	22.6

[a]Source: References; Wheat, Tennessee.

Table A.67. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Texas, 1929 to 1959[a]

Variety	Texas Test Yields No. of Tests	Texas Test Yields % of Kharkof	Estimated Percentage of Acreage Planted to Specified Varieties 29	34	39	44	49	54	59
Turkey	24	100	51.4	51.6	37.7	21.6	1.4	.5	.4
Mediterranean	21	103	9.8	5.3	5.4	4.5	2.7	1.8	1.1
Blackhull	64	107	13.2	22.9	40.8	22.7	6.8	2.8	.9
Kanred	48	108	19.8	16.1	6.0	6.9	1.3	.3	.1
Tenmarq	71	108		.2	6.7	30.9	7.6	2.0	2.1
Early Black	70	107			.5	2.9	8.7	1.7	
Chiefkan	32	116			.4	5.7	.9	1.5	.1
Comanche	63	117				.3	11.3	10.6	8.7
Triumph	28	103					17.1	17.1	30.3
Wichita	41	106					7.9	26.3	16.9
Blue Jacket	6	109					.1	5.4	
Westar	33	117					26.0	20.0	6.7
Quanah	20	99						1.4	3.2
Apache	11	106						.1	2.0
Concho	21	114							12.2
Crocket	22	117							7.9
Others			5.8	3.9	2.5	4.5	8.2	8.5	7.4

[a]Source: References; Wheat, Texas.

Table A.68. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Virginia, 1939 to 1959[a]

Variety	Appalachian Test Yields No. of Tests	Appalachian Test Yields % of Trumbull	Estimated Percentage of Acreage Planted to Specified Varieties 39	44	49	54	59
Fulcaster	30	97.3	30.5	21.6	3.5	1.0	
Redhart	32	87.5	.7	20.0	16.2	5.1	2.5
Purplestraw	68	90.0	3.2	2.5	1.6	1.4	.6
Forward	16	92.0	7.8	4.4	7.3	1.5	.4
Leap	61	98.5	21.0	19.2	8.8	2.9	2.4
Thorne	44	112.1			17.1	36.6	31.4
Vahart	16	117.5			12.0	23.8	11.5
Atlas 66	49	111.1				3.7	8.2
Atlas 50	37	115.2				2.2	.3
Seneca	13	120.3				2.3	21.0
Anderson	52	121.0				2.0	8.5
Others			36.8	32.3	33.5	17.5	13.2

[a]Source: References; Wheat, Virginia.

Table A.69. Relative test yields and acreage distribution of wheat varieties, at five year intervals, West Virginia, 1939 to 1959[a]

Variety	Appalachian Test Yields No. of Tests	Appalachian Test Yields % of Trumbull	Estimated Percentage of Acreage Planted to Specified Varieties 39	44	49	54	59
Mediterranean	2	70.2	2.8				
Forward	16	92.0	1.5	3.5	.4	1.0	
Leap	61	98.5	28.8	36.5	4.4	.1	
Fulcaster	30	97.3	24.5	37.4	7.8	.9	2.1
Trumbull	105	100.0	3.3	3.0	2.6		.3
Nittany	27	100.3	4.4	2.2	1.7	.5	.5
Redhart	32	87.5		.4	1.8	.6	
Purplestraw	68	90.0		.3	.7	1.5	
Thorne	44	112.1		6.0	49.6	70.4	56.1
Carala	27	97.5			1.3	4.6	
Vigo	12	104.5				.9	1.5
Pennoll	22	112.3				.3	2.0
Seneca	13	120.3				1.8	12.1
Anderson	52	121.0				2.2	3.0
Knox	66	109.3					1.7
Dual	44	122.3					1.2
Others			34.7	10.7	29.7	15.2	19.5

[a]Source: References; Wheat, West Virginia.

Table A.70. Relative test yields and acreage distribution of wheat varieties, at five year intervals, Wisconsin, 1939 to 1959[a]

Variety	Wisconsin Test Yields: No. of Tests	Wisconsin Test Yields: % of Thatcher	Estimated Percentage of Acreage Planted to Specified Varieties: 39	44	49	54	59
Marquis	20	88.0	9.1	4.1			
Thatcher	19	100.0	6.4	7.6	.1		
Progress	5	110.4	33.2	24.5	.9	.2	
Sturgeon	16	116.0	5.8	7.4	.9	.8	
Rival	9	101.2		.3	.3		
Regent	6	101.3		.2	.2	.3	
Henry	19	125.8		.1	71.8	61.6	20.8
Mida	12	106.0			.1		
Pilot	8	107.5			.2		
Rushmore	6	111.0				1.4	
Lee	13	120.5				.7	
Selkirk	8	131.9				.2	10.3
Russell	14	123.8					11.6
Other			45.5	55.8	25.5	34.8	57.3

[a]Source: References; Wheat, Wisconsin.

XI. APPENDIX B

Table B.1. Annual corn hybrid indices by states, base period 1947-1949[a]

Year	Arkansas	Illinois	Indiana	Iowa	Kansas	Michigan
		Corn Hybrid Indices				
1934		.82		.77		
1935		.82		.77		
1936		.82		.78		
1937		.85	.83	.81		.79
1938		.88	.85	.84		.79
1939		.90	.88	.88	.86	.80
1940		.92	.90	.92	.87	.82
1941		.94	.94	.94	.88	.87
1942	.85	.96	.96	.95	.89	.90
1943	.86	.97	.97	.96	.90	.92
1944	.88	.97	.98	.97	.93	.94
1945	.91	.98	.98	.98	.95	.96
1946	.95	.99	.99	.98	.98	.98
1947	.98	.99	.99	.99	.99	.99
1948	1.00	1.00	1.00	1.00	1.00	1.00
1949	1.02	1.00	1.00	1.01	1.01	1.01
1950	1.05	1.01	1.01	1.02	1.02	1.02
1951	1.07	1.02	1.02	1.02	1.02	1.03
1952	1.10	1.02	1.02	1.03	1.04	1.04
1953	1.13	1.03	1.03	1.04	1.04	1.05
1954	1.15	1.03	1.03	1.05	1.05	1.06
1955	1.17	1.04	1.04	1.06	1.06	1.08
1956	1.19	1.05	1.04	1.07	1.06	1.08
1957	1.21	1.05	1.05	1.08	1.07	1.10
1958	1.23	1.06	1.05	1.08	1.07	1.10
1959	1.25	1.06	1.06	1.09	1.08	1.11
1960	1.26	1.07	1.07	1.10	1.09	1.12
1961	1.27	1.07	1.07	1.11	1.10	1.13
	Minnesota	Mississippi	Missouri	Nebraska	New Jersey	N. Dakota
1937	.80		.78	.81		
1938	.82		.79	.81		
1939	.85	.97	.80	.82		
1940	.88	.97	.83	.84	.89	
1941	.91	.97	.87	.86	.91	
1942	.94	.97	.90	.89	.92	
1943	.95	.97	.93	.91	.95	
1944	.96	.98	.95	.94	.96	.99
1945	.97	.98	.97	.96	.97	.99

[a]Source: References; Corn.

Table B.1 (Continued)

Year	Minnesota	Mississippi	Missouri	Nebraska	New Jersey	N. Dakota
			Corn Hybrid Indices			
1946	.98	.98	.98	.98	.98	.99
1947	.99	.99	.99	.99	1.00	1.00
1948	1.00	1.00	1.00	1.00	.99	1.00
1949	1.01	1.01	1.01	1.01	1.01	1.00
1950	1.02	1.01	1.02	1.01	1.03	1.01
1951	1.02	1.04	1.02	1.02	1.04	1.01
1952	1.04	1.05	1.03	1.03	1.05	1.02
1953	1.04	1.07	1.03	1.04	1.06	1.02
1954	1.05	1.08	1.04	1.05	1.07	1.02
1955	1.06	1.10	1.05	1.06	1.08	1.03
1956	1.07	1.11	1.06	1.06	1.09	1.03
1957	1.08	1.14	1.06	1.07	1.10	1.04
1958	1.08	1.16	1.07	1.09	1.11	1.05
1959	1.09	1.17	1.07	1.10	1.12	1.05
1960	1.10	1.19	1.08	1.11	1.12	1.06
1961	1.10	1.19	1.08	1.11	1.13	1.06

	N. Carolina	Ohio	Oklahoma	S. Dakota	Tennessee	Texas	Wisconsin
1937				.90		.78	.78
1938				.90			.80
1939		.88		.90			.83
1940		.91		.90			.86
1941		.95		.92		.85	.89
1942	.96	.97		.93		.85	.91
1943	.96	.98	.84	.94	.98	.85	.93
1944	.96	.99	.85	.95	.99	.85	.94
1945	.96	.99	.87	.97	.99	.88	.96
1946	.96	1.00	.91	.97	.99	.92	.98
1947	.98	1.00	.96	.99	1.00	.96	.99
1948	1.00	1.00	1.01	1.00	1.00	1.02	1.00
1949	1.02	1.00	1.03	1.01	1.00	1.02	1.01
1950	1.03	1.00	1.07	1.02	1.01	1.05	1.03
1951	1.04	1.01	1.09	1.03	1.01	1.08	1.04
1952	1.06	1.01	1.12	1.04	1.02	1.11	1.05
1953	1.06	1.01	1.15	1.05	1.02	1.13	1.06
1954	1.08	1.01	1.13	1.05	1.03	1.13	1.07
1955	1.12	1.01	1.14	1.07	1.03	1.14	1.08
1956	1.16	1.01	1.18	1.08	1.04	1.18	1.09
1957	1.19	1.02	1.19	1.10	1.05	1.20	1.10
1958	1.22	1.02	1.23	1.11	1.05	1.21	1.12
1959	1.25	1.02	1.25	1.12	1.06	1.21	1.13
1960	1.26	1.02	1.27	1.13	1.06	1.24	1.14
1961	1.27	1.02	1.29	1.14	1.07	1.25	1.15

Table B.2. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Arkansas[a]

		Crop Districts									
		1, 2, 4, 5		3		6, 9		7		8	
Relative Corn Acreage		.22		.35		.28		.06		.09	
Open-pollinated Varieties											
Test Period	Test Years	42-49	8	42-49	8	42-48	7	42-49	8	42-49	8
Check Hybrid 1		Ill. 200		Dortch. 110		Dortch. 110		Dortch. 110		Dortch. 110	
Test Period	Test Years	42-55	12	42-50	9	42-50	8	42-51	10	42-50	8
Period Compared	Years Compared	42-49	8	42-49	8	42-48	7	42-49	8	42-49	7
Hybrid 1 Yield /	O-P Yield	154.8		136.8		149.5		128.4		118.3	
Check Hybrid 2		Meach. M-5		Mangel. 148		Miss. US 13		Keyst. 222		Funk G 711	
Test Period	Test Years	45-61	16	47-52	6	43-51	6	47-58	12	45-59	12
Period Compared	Years Compared	45-55	9	47-50	4	43-50	5	47-51	5	45-50	5
Hybrid 2 Yield /	Hybrid 1 Yield	100.0		87.3		93.6		115.6		122.6	
Hybrid 2 Yield /	O-P Yield	154.8		119.4		139.9		148.4		145.0	
Check Hybrid 3		M-33Y		Key. 107W		Meach. M-5		Pag 631W		Key. 222	
Test Period	Test Years	48-61	13	49-58	9	45-60	14	48-58	11	47-56	9
Period Compared	Years Compared	48-61	13	49-52	4	46-51	5	48-58	11	47-56	8
Hybrid 3 Yield /	Hybrid 2 Yield	99.6		100.2		111.6		100.9		106.6	
Hybrid 3 Yield /	O-P Yield	154.2		119.6		156.1		149.7		154.6	
Check Hybrid 4		Dixie 33		Dixie 33		Pag 631W		Dixie 22		Dixie 22	
Test Period	Test Years	50-61	11	50-61	11	48-58	10	50-61	12	50-61	11
Period Compared	Years Compared	50-61	11	50-58	8	48-57	9	50-58	9	50-56	6
Hybrid 4 Yield /	Hybrid 3 Yield	130.1		144.3		105.9		107.5		104.9	
Hybrid 4 Yield /	O-P Yield	200.6		172.6		165.3		160.9		162.2	
Check Hybrid 5		Funk G 512W		McCurdy 988		Texas 30		Coker 911		Dixie 33	
Test Period	Test Years	55-61	7	52-61	9	52-60	8	52-61	10	50-61	11
Period Compared	Years Compared	55-61	7	52-61	9	52-57	6	52-61	10	50-61	11
Hybrid 5 Yield /	Hybrid 4 Yield	91.3		85.7		116.6		100.6		110.7	
Hybrid 5 Yield /	O-P Yield	183.1		147.9		192.7		161.9		179.6	

[a]Source: References; Corn, Arkansas.

Table B.3. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Illinois[a]

		Crop Districts											
		North		West		Central		East		South Central		South	
Relative Corn Acreage		.30		.10		.15		.15		.20		.10	
Open-pollinated Varieties													
Test Period	Test Years	34-41	8	34-41	8	34-41	8	35-41	7	34-41	8	35-41	7
Check Hybrid 1		Ill. 751		U.S. 44		Ill. 784		Funk G 212		Ill. 784		Ill. 784	
Test Period	Test Years	35-51	16	35-46	11	38-43	5	36-43	7	37-51	12	36-51	13
Period Compared	Years Compared	35-41	7	35-41	7	38-41	4	36-41	6	37-41	5	36-41	4
Hybrid 1 Yield /	O-P Yield	120.6		124.6		120.6		123.9		130.1		127.4	
Check Hybrid 2		Ill. 101		U.S. 13		U.S. 13		U.S. 13		Funk G 80		Wisn. 917	
Test Period	Test Years	41-57	16	41-58	16	39-58	19	39-57	14	39-52	11	43-54	12
Period Compared	Years Compared	41-51	10	41-46	5	39-43	4	39-43	4	39-51	9	42-51	9
Hybrid 2 Yield /	Hybrid 1 Yield	97.8		106.3		101.4		97.3		100.9		115.3	
Hybrid 2 Yield /	O-P Yield	117.9		132.4		122.3		120.6		131.3		146.9	
Check Hybrid 3		Ill.1091A		Pioneer 313		Ill. 21		Frey 645		U.S. 13		Pioneer 300	
Test Period	Test Years	44-55	12	47-58	12	44-57	14	44-56	9	39-58	17	48-60	13
Period Compared	Years Compared	44-55	12	47-58	11	44-57	14	44-56	9	39-52	11	48-54	7
Hybrid 3 Yield /	Hybrid 2 Yield	105.2		105.9		99.0		96.5		99.3		112.2	
Hybrid 3 Yield /	O-P Yield	124.0		140.2		121.1		116.4		130.4		164.8	
Check Hybrid 4		Frey 410		Holmes 39		AES 805		Frey 644		Pioneer 302		Dekalb 925	
Test Period	Test Years	48-60	12	50-60	11	52-60	9	44-60	12	47-59	12	53-60	8
Period Compared	Years Compared	48-55	7	50-58	9	52-57	6	44-56	8	47-58	11	53-60	8
Hybrid 4 Yield /	Hybrid 3 Yield	97.5		99.3		102.6		102.8		103.6		106.0	
Hybrid 4 Yield /	O-P Yield	120.9		139.2		124.2		119.7		135.1		174.7	
Check Hybrid 5		Sieben S340		Null		Frey 892		Frey 692		Producer 13-1			
Test Period	Test Years	46-60	15	53-60	8	53-60	8	44-60	12	53-59	7		
Period Compared	Years Compared	48-60	12	53-60	8	53-60	8	44-60	12	53-59	7		
Hybrid 5 Yield /	Hybrid 4 Yield	101.6		104.2		105.0		99.8		113.7			
Hybrid 5 Yield /	O-P Yield	122.8		145.0		130.4		119.5		153.6			

[a]Source: References; Corn, Illinois.

Table B.4. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Indiana[a]

		Corn Test Districts									
		Porter		Jay		Tippecan.		Rush		Daviess	
Relative Corn Acreage		.21		.13		.25		.28		.13	
Open-pollinated Varieties											
Test Period	Test Years	37-42	5	31-41	11	31-42	11	38-42	4	--	
Check Hybrid 1		Ind. 610 B		Hybrid 660		Hybrid 660				U.S. 13	
Test Period	Test Years	37-48	12	31-36	6	31-36	6			38-60	22
Period Compared	Years Compared	37-42	5	31-36	6	31-36	6			--	
Hybrid 1 Yield /	O-P Yield	121.9		110.4		123.7				133.2	
Check Hybrid 2		Ind. 210B		Ind. 610B		Ind. 610B		Ind. 610B		Ind. 909A	
Test Period	Test Years	38-52	15	37-48	8	37-48	12	38-48	10	40-57	18
Period Compared	Years Compared	38-48	11	37-41	5	37-42	5	38-42	4	40-57	13
Hybrid 2 Yield /	Hybrid 1 Yield	97.5		--		--		--		107.2	
Hybrid 2 Yield /	O-P Yield	118.9		119.9		122.7		118.1		135.1	
Check Hybrid 3		U.S. 13		U.S. 13		U.S. 13		U.S. 13		Conn 870	
Test Period	Test Years	38-60	22	38-58	16	40-61	21	39-61	23	51-60	10
Period Compared	Years Compared	40-52	13	38-48	7	40-48	9	39-48	9	51-57	7
Hybrid 3 Yield /	Hybrid 2 Yield	101.9		100.2		101.7		112.8		89.8	
Hybrid 3 Yield /	O-P Yield	121.2		120.1		124.8		133.2		121.3	
Check Hybrid 4		Ind. 252A		Ind. 210B		Ind. 909A		Ind. 909A			
Test Period	Test Years	48-61	14	42-52	7	46-57	12	46-55	9		
Period Compared	Years Compared	48-60	13	42-50	5	46-57	12	46-55	9		
Hybrid 4 Yield /	Hybrid 3 Yield	99.5		97.4		103.5		93.7			
Hybrid 4 Yield /	O-P Yield	120.6		117.0		129.2		124.8			

[a]Source: References; Corn, Indiana.

Table B.4 (Continued)

		Corn Test Districts								
		Porter		Jay		Tippecan.		Rush		Daviess
Check Hybrid 5		Iowa 4308		Ind. 252A		Ind. 344D		Ind. 844D		
Test Period	Test Years	51-61	11	48-58	10	39-60	11	38-61	12	
Period Compared	Years Compared	51-60	10	48-52	5	51-57	7	51-55	5	
Hybrid 5 Yield /	Hybrid 4 Yield	97.9		104.7		94.3		110.4		
Hybrid 5 Yield /	O-P Yield	118.1		122.5		121.8		137.8		
Check Hybrid 6						Cribfiller 70				
Test Period	Test Years					57-61	5			
Period Compared	Years Compared					57-60	4			
Hybrid 6 Yield /	Hybrid 5 Yield					115.4				
Hybrid 6 Yield /	O-P Yield					140.6				

Table B.5. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Iowa[a]

		Corn Test Districts									
		1		2		3		4		5	
Relative Corn Acreage		Same for all districts.									
Open-pollinated Varieties											
Test Period	Test Years	30-40	11	32-40	9	30-39	10	30-40	10	30-40	11
Check Hybrid 1		Ia 931		Ia 931		Ia 931		Ia 939		Ia 939	
Test Period	Test Years	32-46	13	32-46	12	31-46	12	31-49	17	31-49	17
Period Compared	Years Compared	32-40	8	32-40	7	31-39	7	31-40	8	31-40	8
Hybrid 1 Yield /	O-P Yield	116.7		121.8		119.2		122.9		121.0	
Check Hybrid 2		Pioneer 353A		Ia 4316		Ia 4316		Ia 306		Ace 395	
Test Period	Test Years	41-50	8	42-56	13	42-55	12	40-53	14	40-50	11
Period Compared	Years Compared	41-46	4	42-46	4	42-46	4	40-49	10	40-49	10
Hybrid 2 Yield /	Hybrid 1 Yield	105.0		110.1		124.3		103.4		105.4	
Hybrid 2 Yield /	O-P Yield	122.5		134.1		148.2		127.1		127.5	
Check Hybrid 3		Ia 4316		Ia 4417		Pioneer 349		Ia 4249		Ia 4298	
Test Period	Test Years	42-60	18	46-60	14	47-60	13	43-60	18	43-60	18
Period Compared	Years Compared	42-50	7	46-56	10	47-55	8	43-53	11	43-50	8
Hybrid 3 Yield /	Hybrid 2 Yield	107.8		110.0		104.5		106.2		107.7	
Hybrid 3 Yield /	O-P Yield	132.1		134.1		154.9		135.0		137.3	
Check Hybrid 4		Pioneer 352		Pag 277		Pag 277		Pag 381		Ia 4376	
Test Period	Test Years	48-60	13	51-60	10	51-60	10	55-60	6	49-60	12
Period Compared	Years Compared	48-60	13	51-60	10	51-60	10	55-60	6	49-60	12
Hybrid 4 Yield /	Hybrid 3 Yield	102.8		113.9		99.6		110.8		104.2	
Hybrid 4 Yield /	O-P Yield	135.8		152.7		154.3		149.6		143.1	

[a]Source: References; Corn, Iowa.

Table B.5 (Continued)

		Corn Test Districts											
		6		7		8		9		10		12	
Relative Corn Acreage		Same for all districts.											
Open-pollinated Varieties													
Test Period	Test Years	30-40	11	30-40	9	30-40	11	30-40	11	30-40	8	30-40	8
Check Hybrid 1		Ia 939		Ia 939		Ia 939		Ia 939		U S 44		U S 44	
Test Period	Test Years	31-49	17	32-48	13	35-48	14	34-48	11	37-43	7	37-43	7
Period Compared	Years Compared	31-40	8	32-40	5	35-40	6	34-40	5	37-40	4	37-40	4
Hybrid 1 Yield /	O-P Yield	114.5		121.5		113.8		116.8		133.5		119.0	
Check Hybrid 2		Ace 395		Maygold 49		Maygold 49		Maygold 49		U S 13		U S 13	
Test Period	Test Years	40-50	11	40-54	15	40-54	15	40-54	13	39-59	17	39-57	19
Period Compared	Years Compared	40-49	10	40-48	9	40-48	9	40-48	7	39-43	5	39-43	5
Hybrid 2 Yield /	Hybrid 1 Yield	108.0		105.3		111.1		112.1		112.4		103.2	
Hybrid 2 Yield /	O-P Yield	123.7		127.9		126.4		130.9		150.1		122.8	
Check Hybrid 3		Ia 4298		Ohio C92		Ohio C92		Ohio C92		Ohio C92		Ohio C92	
Test Period	Test Years	43-56	14	44-60	17	44-57	14	45-60	16	42-60	15	42-57	16
Period Compared	Years Compared	43-50	8	44-54	11	44-54	11	45-54	10	42-59	14	42-57	16
Hybrid 3 Yield /	Hybrid 2 Yield	108.8		106.1		106.3		106.1		101.1		103.1	
Hybrid 3 Yield /	O-P Yield	134.6		135.7		134.4		138.9		151.8		126.6	
Check Hybrid 4		Ia 4376		Maygold59A		Aes 801		Pioneer 345		Maygold 59A		Funk G 95A	
Test Period	Test Years	49-60	12	53-60	8	49-60	12	53-60	8	49-60	10	53-61	8
Period Compared	Years Compared	49-56	8	53-61	9	49-57	9	53-60	8	49-60	10	53-57	5
Hybrid 4 Yield /	Hybrid 3 Yield	105.6		104.9		102.1		105.0		100.9		99.4	
Hybrid 4 Yield /	O-P Yield	142.1		142.3		137.2		145.8		153.2		125.8	
Check Hybrid 5		Pioneer 352										AES 806	
Test Period	Test Years	49-60	12									54-60	7
Period Compared	Years Compared	49-60	12									54-60	7
Hybrid 5 Yield /	Hybrid 4 Yield	102.6										103.3	
Hybrid 5 Yield /	O-P Yield	145.8										130.0	

Table B.6. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Kansas[a]

		Crop Districts 1		2		3		4		5, 6, 7	
Relative Corn Acreage		.30		.21		.18		.16		.15	
Open-pollinated Varieties											
Test Period	Test Years	39-61	21	39-61	21	40-61	16	39-61	18	39-61	20
Check Hybrid 1		U.S. 35		U.S. 35		Funk G 88		U.S. 13		U.S. 35	
Test Period	Test Years	39-47	9	39-44	6	40-44	4	39-57	13	39-47	9
Period Compared	Years Compared	39-47	9	39-44	6	40-44	4	39-57	13	39-47	9
Hybrid 1 Yield /	O-P Yield	121.0		119.8		114.0		123.6		119.0	
Check Hybrid 2		Kans. 2234		U.S.13		U.S. 13		Kans. 2234		U.S. 13	
Test Period	Test Years	41-48	8	39-58	18	40-58	14	42-57	14	39-58	17
Period Compared	Years Compared	41-47	7	39-44	6	40-44	4	42-57	12	39-47	9
Hybrid 2 Yield /	Hybrid 1 Yield	102.6		97.0		91.9		102.6		101.7	
Hybrid 2 Yield /	O-P Yield	124.1		116.2		104.8		126.8		121.0	
Check Hybrid 3		Kans. 1585		Kans. 1585		Kans. 1585		Mayg. 59A		Kans. 1585	
Test Period	Test Years	41-52	11	41-57	15	41-57	13	50-61	10	42-51	10
Period Compared	Years Compared	41-48	8	41-57	15	41-57	13	50-57	7	42-51	10
Hybrid 3 Yield /	Hybrid 2 Yield	101.6		99.7		97.2		98.7		110.6	
Hybrid 3 Yield /	O-P Yield	126.1		115.9		101.9		125.2		133.8	
Check Hybrid 4		Mayg. 59A		Pioneer 302		Mayg. 59A		Pioneer 312A		Kans. 1639	
Test Period	Test Years	46-61	14	47-58	10	46-58	9	54-61	7	44-61	14
Period Compared	Years Compared	46-52	6	47-57	9	46-57	8	54-61	7	44-51	7
Hybrid 4 Yield /	Hybrid 3 Yield	109.4		112.4		109.3		109.3		95.6	
Hybrid 4 Yield /	O-P Yield	138.0		130.3		111.4		136.8		127.9	

[a]Source: References; Corn, Kansas.

Table B.6 (Continued)

		Crop Districts 1		2		3		4	5, 6, 7	
Check Hybrid 5		Kans 1859		Mayg. 47		Pioneer 312A			Pioneer 312A	
Test Period	Test Years	50-61	11	52-61	10	53-61	5		54-61	6
Period Compared	Years Compared	50-61	11	52-58	7	53-58	4		54-61	6
Hybrid 5 Yield /	Hybrid 4 Yield	100.5		99.3		114.6			114.3	
Hybrid 5 Yield /	O-P Yield	138.7		129.4		127.7			146.2	
Check Hybrid 6				Pioneer 302B						
Test Period	Test Years			58-61	4					
Period Compared	Years Compared			58-61	4					
Hybrid 6 Yield /	Hybrid 5 Yield			102.5						
Hybrid 6 Yield /	O-P Yield			132.6						

Table B.7. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Michigan[a]

		Crop Districts 1, 2, 3		4, 5		6		7, 8		9	
Relative Corn Acreage		.05		.12		.10		.47		.26	
Open-pollinated Varieties											
Test Period	Test Years	38-41	4	40-41	2	38-41	4	38-41	4	38-41	4
Check Hybrid 1		Minn. 402		Mich. 1218		Mich. 1218		Mich. 1218		Pioneer 322	
Test Period	Test Years	38-43	5	40	1	38-41	4	38-41	4	38-51	14
Period Compared	Years Compared	38-41	4	40	1	38-41	4	38-41	4	38-41	4
Hybrid 1 Yield /	O-P Yield	112.4		99.6		107.3		103.5		152.0	
Check Hybrid 2		Mich. 51B		Mich. 51B		Pioneer 355		Pioneer 322		Mich. 24B	
Test Period	Test Years	39-54	13	40-54	13	40-46	7	38-50	10	41-50	10
Period Compared	Years Compared	39-43	4	40-41	2	40-41	2	38-41	4	41-50	8
Hybrid 2 Yield /	Hybrid 1 Yield	105.0								87.7	
Hybrid 2 Yield /	O-P Yield	118.0		104.2		134.6		128.0		133.3	
Check Hybrid 3		Mich 11A		Ohio M15		Mich 36B		Mich 24B		Wolv. 83	
Test Period	Test Years	43-54	10	41-53	13	41-51	11	41-51	11	48-61	14
Period Compared	Years Compared	43-54	10	41-53	7	41-46	5	41-50	7	48-51	4
Hybrid 3 Yield /	Hybrid 2 Yield	98.4		111.4		93.7		95.9			
Hybrid 3 Yield /	O-P Yield	116.1		116.1		126.1		122.8		152.9	
Check Hybrid 4		Mich. 250		Pioneer 373		Mich. 51B		Pioneer 373		Mich 250	
Test Period	Test Years	51-61	11	44-54	11	41-53	13	43-54	12	51-61	11
Period Compared	Year Compared	51-54	4	44-54	9	41-51	10	43-51	9	52-61	10
Hybrid 4 Yield /	Hybrid 3 Yield	125.3				96.7		108.1		89.2	
Hybrid 4 Yield /	O-P Yield	145.5		123.3		121.9		132.7		136.4	

[a]Source: References; Corn, Michigan

Table B.7 (Continued)

		Crop Districts 1, 2, 3		4, 5		6		7, 8		9	
Check Hybrid 5		Mich 350		Mich 11A		Pioneer 349		Pioneer 349		Mich 300	
Test Period	Test Years	51-61	11	44-54	11	47-59	13	47-58	12	57-61	5
Period Compated	Year Compared	51-61	11	44-54	10	47-53	7	47-54	8	57-61	5
Hybrid 5 Yield /	Hybrid 4 Yield	95.6				132.2		106.5		110.6	
Hybrid 5 Yield /	O-P Yield	139.1		101.4		161.2		141.3		150.9	
Check Hybrid 6				Mich. 250		Mich 250		Mich. 250			
Test Period	Test Years			51-61	11	51-61	11	51-61	11		
Period Compared	Years Compared			51-54	4	51-59	9	51-58	8		
Hybrid 6 Yield /	Hybrid 5 Yield					86.3		90.9			
Hybrid 6 Yield /	O-P Yield			122.6		139.1		128.4			
Check Hybrid 7				Mich 350		Mich. 350		Mich. 350			
Test Period	Test Years			51-61	11	51-61	11	51-61	11		
Period Compared	Years Compared			51-61	10	51-61	11	51-61	11		
Hybrid 7 Yield /	Hybrid 6 Yield			100.5		98.4		98.4			
Hybrid 7 Yield /	O-P Yield			123.2		136.9		126.3			

Table B.8. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Minnesota[a]

		Corn Test Districts									
		1, 2		3, 4		5		6		7	
Relative Corn Acreage		.44		.34		.13		.06		.03	
Open-pollinated Varieties											
Test Period	Test Years	37-55	17	37-49	12	37-49	11	38-49	11	42-50	9
Check Hybrid 1		Minn. 403		Minn. 301		Minn. 401		Minn. 401		Minn. 800	
Test Period	Test Years	37-49	12	37-47	10	37-43	5	38-43	5	42-53	12
Period Compared	Years Compared	37-49	12	37-47	10	37-43	5	38-43	5	42-50	9
Hybrid 1 Yield /	O-P Yield	123.0		119.9		103.4		119.6		115.2	
Check Hybrid 2		Minn. 406		Minn. 403		Minn. 602		Minn. 402		No. Dak. 301	
Test Period	Test Years	42-54	12	37-48	11	40-53	13	38-43	6	44-56	12
Period Compared	Years Compared	42-49	7	37-47	10	40-49	9	38-43	6	44-53	9
Hybrid 2 Yield /	Hybrid 1 Yield	118.0		96.7						111.2	
Hybrid 2 Yield /	O-P Yield	145.1		115.9		112.8		101.8		128.1	
Check Hybrid 3		Minn. 408		Minn. 503		Minn. 608		Minn. 702		Minn. 802	
Test Period	Test Years	42-57	15	42-56	13	45-58	14	42-52	10	49-55	7
Period Compared	Years Compared	42-54	12	42-48	5	45-53	9	42-49	7	50-55	6
Hybrid 3 Yield /	Hybrid 2 Yield	103.4		107.2		101.2				100.3	
Hybrid 3 Yield /	O-P Yield	150.0		124.2		114.2		110.2		128.5	
Check Hybrid 4		Minn. 412		Minn. 507		Minn. 611		Minn. 706		Minn. 804	
Test Period	Test Years	52-61	10	48-61	14	54-61	8	44-55	11	53-58	6
Period Compared	Years Compared	52-57	6	48-56	9	54-58	5	44-52	8	53-56	4
Hybrid 4 Yield /	Hybrid 3 Yield	104.7		101.1		98.7		110.4		112.6	
Hybrid 4 Yield /	O-P Yield	157.0		125.6		112.7		121.7		144.7	

[a]Source: References; Corn, Minnesota.

Table B.8 (Continued)

		Corn Test Districts									
		1, 2		3, 4		5		6		7	
Check Hybrid 5		Minh. 414		Minh. 511		Minh. 612		Minh. 711		Minh. 803	
Test Period	Test Years	55-61	7	55-61	7	54-61	8	51-57	7	54-61	8
Period Compared	Years Compared	55-61	7	55-61	7	54-61	8	51-55	5	54-58	5
Hybrid 5 Yield /	Hybrid 4 Yield	100.1		102.7		98.0		98.7		98.7	
Hybrid 5 Yield /	O-P Yield	157.2		129.0		110.4		120.1		142.3	
Check Hybrid 6		Pioneer 371		Pioneer 377A				Minh. 707		K C 3	
Test Period	Test Years	56-61	6	56-61	6			51-59	8	56-61	6
Period Compared	Years Compared	56-61	6	56-61	6			51-57	6	56-61	6
Hybrid 6 Yield /	Hybrid 5 Yield	105.4		100.5				104.0		103.6	
Hybrid 6 Yield /	O-P Yield	165.7		129.6				124.9		147.4	
Check Hybrid 7								Pioneer 388			
Test Period	Test Years							55-61	6		
Period Compared	Years Compared							55-59	4		
Hybrid 7 Yield /	Hybrid 6 Yield							106.8			
Hybrid 7 Yield /	O-P Yield							133.4			
Check Hybrid 8								Funk G 35A			
Test Period	Test Years							56-61	6		
Period Compared	Years Compared							57-61	5		
Hybrid 8 Yield /	Hybrid 7 Yield							99.6			
Hybrid 8 Yield /	O-P Yield							132.9			

Table B.9. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Mississippi[a]

		Crop Districts		
		1, 2, 3 North	4, 5, 6 Central	7, 8, 9 South
Relative Corn Acreage		.33	.34	.33
Open-pollinated Varieties				
Test Period	Test Years	39-57 18	39-57 18	39-57 18
Check Hybrid 1		Tenn. 15	Tenn. 15	Tenn. 15
Test Period	Test Years	39-44 6	39-44 6	39-44 6
Period Compared	Years Compared	39-44 6	39-44 6	39-44 6
Hybrid 1 Yield /	O-P Yield	118.7	117.9	113.4
Check Hybrid 2		Tenn. 10	Tenn. 10	Tenn. 10
Test Period	Test Years	40-49 9	40-49 9	40-48 8
Period Compared	Years Compared	40-44 5	40-44 5	40-48 8
Hybrid 2 Yield /	Hybrid 1 Yield	102.2	100.7	--
Hybrid 2 Yield /	O-P Yield	121.3	118.7	108.2
Check Hybrid 3		Funk G 714	Funk G 714	Funk G 714
Test Period	Test Years	44-50 6	45-50 5	44-48 4
Period Compared	Years Compared	44-49 5	45-49 4	44-48 4
Hybrid 3 Yield /	Hybrid 2 Yield	101.8	99.9	--
Hybrid 3 Yield /	O-P Yield	123.5	118.6	114.1
Check Hybrid 4		Dixie 11	Dixie 11	Dixie 11
Test Period	Test Years	46-56 10	46-56 10	46-56 10
Period Compared	Years Compared	46-50 4	46-50 4	45-56 10
Hybrid 4 Yield /	Hybrid 3 Yield	108.1	120.6	--
Hybrid 4 Yield /	O-P Yield	133.5	143.0	128.4
Check Hybrid 5		Dixie 22	Dixie 22	Dixie 18
Test Period	Test Years	49-61 13	49-61 12	48-61 14
Period Compared	Years Compared	49-56 8	49-56 7	48-56 9
Hybrid 5 Yield /	Hybrid 4 Yield	101.2	101.9	97.0
Hybrid 5 Yield /	O-P Yield	135.1	145.7	124.5
Check Hybrid 6		Pag 653W	Dixie 82	Coker 811
Test Period	Test Years	57-61 5	51-61 11	51-61 10
Period Compared	Years Compared	57-61 5	51-61 10	51-61 10
Hybrid 6 Yield /	Hybrid 5 Yield	99.3	105.4	102.9
Hybrid 6 Yield /	O-P Yield	134.2	153.6	128.1

[a]Source: References; Corn, Mississippi.

Table B.10. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Missouri[a]

		Corn Test Districts					
		North		Central		South	
Relative Corn Acreage		.45		.35		.25	
Open-pollinated Varieties							
Test Period	Test Years	37-42	6	37-42	5	37-42	6
Check Hybrid 1		Mo. 47		Mo. 47		Mo. 47	
Test Period	Test Years	37-42	6	37-42	6	37-42	6
Period Compared	Years Compared	37-42	6	37-42	6	37-42	6
Hybrid 1 Yield /	O-P Yield	121.6		125.2		124.8	
Check Hybrid 2		Mo. 8		Mo. 8		Mo. 8	
Test Period	Test Years	37-48	9	37-55	15	37-55	15
Period Compared	Years Compared	37-42	6	37-42	6	37-42	6
Hybrid 2 Yield /	O-P Yield	117.7		115.9		121.0	
Check Hybrid 3		U.S. 13		U.S. 13		U.S. 13	
Test Period	Test Years	39-61	19	39-61	18	40-61	18
Period Compared	Years Compared	39-48	6	39-55	13	40-55	12
Hybrid 3 Yield /	Hybrid 2 Yield	109.8		108.5		101.9	
Hybrid 3 Yield /	O-P Yield	129.2		125.8		123.3	
Check Hybrid 4		Ohio C92		Kans. 1639		Kans. 1639	
Test Period	Test Years	47-60	14	47-61	15	47-61	15
Period Compared	Years Compared	47-60	14	47-61	15	47-61	15
Hybrid 4 Yield /	Hybrid 3 Yield	100.1		104.2		98.1	
Hybrid 4 Yield /	O-P Yield	129.3		131.1		121.0	
Check Hybrid 5		Kans. 1639		U.S. 523W		U.S. 523W	
Test Period	Test Years	47-61	15	49-61	13	48-61	14
Period Compared	Years Compared	47-60	14	49-61	13	48-61	14
Hybrid 5 Yield /	Hybrid 4 Yield	104.5		112.4		118.1	
Hybrid 5 Yield /	O-P Yield	135.1		147.4		142.9	
Check Hybrid 6		U.S. 523W					
Test Period	Test Years	48-61	14				
Period Compared	Years Compared	48-61	14				
Hybrid 6 Yield /	Hybrid 5 Yield	104.5					
Hybrid 6 Yield /	O-P Yield	141.2					

[a]Source: References; Corn, Missouri.

Table B.11. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Nebraska[a]

		Crop Districts											
		1, 2		3		4, 5		6		7		8	
Relative Corn Acreage		.05		.25		.20		.25		.10		.15	
Open-pollinated Varieties													
Test Period	Test Years	39-61	16	33-45	10	39-46	6	33-45	10	41-46	4	35-44	8
Check Hybrid 1		Nebr. 301		Iowa 939		U.S. 35		U.S. 35		U.S. 13		U.S. 13	
Test Period	Test Years	46-61	15	33-46	11	41-48	6	41-48	7	41-52	9	39-50	10
Period Compared	Years Compared	46-61	10	33-45	10	41-46	4	41-45	4	41-45	3	39-44	5
Hybrid 1 Yield /	O-P	113.5		124.7		113.1		124.4		110.5		127.2	
Check Hybrid 2		Ia. 4417		U.S. 35		Iowa 4059		Ohio C92		Nebr. 501		Ohio C92	
Test Period	Test Years	46-61	15	41-48	7	44-49	6	44-51	8	46-59	12	44-59	13
Period Compared	Years Compared	46-61	15	41-46	5	44-48	5	44-48	5	46-52	6	44-50	6
Hybrid 2 Yield /	Hybrid 1 Yield	102.0		104.4		102.2		103.2		112.6		98.1	
Hybrid 2 Yield /	O-P Yield	115.8		130.2		115.6		128.4		124.4		124.8	
Check Hybrid 3		Nebr. 201		Iowa 4316		Nebr. 502		AES 803		Nebr. 504		Nebr. 801W	
Test Period	Test Years	54-61	8	42-54	10	46-59	14	47-61	15	47-61	13	47-61	13
Period Compared	Years Compared	54-61	8	42-46	4	46-49	4	47-52	6	47-59	11	47-59	11
Hybrid 3 Yield /	Hybrid 2 Yield	104.8		98.5		107.0		102.3		91.6		108.5	
Hybrid 3 Yield /	O-P Yield	121.4		128.2		123.7		131.4		114.0		135.4	
Check Hybrid 4				Nebr. 502		Nebr. 504		AES 806		AES 803		AES 803	
Test Period	Test Years			46-59	12	47-61	15	52-61	10	47-61	13	52-61	9
Period Compared	Years Compared			46-54	7	47-59	13	52-61	10	47-61	13	52-61	9
Hybrid 4 Yield /	Hybrid 3 Yield			111.8		102.9		110.0		101.9		97.1	
Hybrid 4 Yield /	O-P Yield			143.3		127.3		144.5		116.2		131.5	

[a]Source: References; Corn, Nebraska.

Table B.11 (Continued)

		Crop Districts 1, 2	3		4, 5		6		7		8
Check Hybrid 5			Nebr. 301		Nebr. 703		Mayg. 59A		AES 806		
Test Period	Test Years		49-61	11	56-61	6	55-61	7	52-61	9	
Period Compared	Years Compared		49-59	9	56-61	6	55-61	7	52-61	9	
Hybrid 5 Yield /	Hybrid 4 Yield		100.5		104.1		92.8		105.8		
Hybrid 5 Yield /	O-P Yield		144.0		132.5		134.1		122.9		
Check Hybrid 6			Nebr. 504								
Test Period	Test Years		50-61	10							
Period Compared	Years Compared		50-61	10							
Hybrid 6 Yield /	Hybrid 5 Yield		106.8								
Hybrid 6 Yield /	O-P Yield		153.8								

Table B.12. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, New Jersey[a]

		Corn Test Districts					
		North		Central		South	
Relative Corn Acreage		Same for all districts.					
Open-pollinated Varieties							
Test Period	Test Years	40-43	4	40-43	4	40-43	4
Check Hybrid 1		N.J. 2		N.J. 2		N.J. 4	
Test Period	Test Years	40-47	8	40-52	9	40-51	12
Period Compared	Years Compared	40-43	4	40-43	4	40-43	4
Hybrid 1 Yield /	O-P Yield	113.0		127.6		117.2	
Check Hybrid 2		N.J. 4		U.S. 13		U.S. 13	
Test Period	Test Years	40-51	12	40-60	18	40-60	19
Period Compared	Years Compared	40-43	4	40-52	10	40-51	12
Hybrid 2 Yield /	Hybrid 1 Yield	--		102.4		97.3	
Hybrid 2 Yield /	O-P Yield	129.6		130.7		114.0	
Check Hybrid 3		U.S. 13		N.J. 7		N.J. 7	
Test Period	Test Years	40-60	21	47-57	9	47-57	9
Period Compared	Years Compared	40-51	12	47-57	9	47-57	9
Hybrid 3 Yield /	Hybrid 2 Yield	95.9		104.3		99.7	
Hybrid 3 Yield /	O-P Yield	124.3		136.3		113.7	
Check Hybrid 4		N.J. 7		N.J. 8		Conn. 554	
Test Period	Test Years	47-57	11	47-61	10	53-61	8
Period Compared	Years Compared	47-57	11	47-57	5	53-57	4
Hybrid 4 Yield /	Hybrid 3 Yield	104.9		96.8		93.5	
Hybrid 4 Yield /	O-P Yield	130.4		131.9		106.3	
Check Hybrid 5		Conn. 554		Conn. 554		N.J. 8	
Test Period	Test Years	50-61	11	52-61	9	53-61	8
Period Compared	Years Compared	52-57	6	53-61	8	53-61	8
Hybrid 5 Yield /	Hybrid 4 Yield	83.1		91.8		123.7	
Hybrid 5 Yield /	O-P Yield	108.4		121.1		131.5	
Check Hybrid 6		N.J. 8					
Test Period	Test Years	53-61	9				
Period Compared	Years Compared	53-61	9				
Hybrid 6 Yield /	Hybrid 5 Yield	122.0					
Hybrid 6 Yield /	O-P Yield	132.2					

[a]Source: References; Corn, New Jersey.

Table B.13. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, North Dakota[a]

		Crop Districts							
		1, 2, 3		4, 5, 6		7, 8		9	
Relative Corn Acreage		.11		.35		.30		.24	
Open-pollinated Varieties									
Test Period	Test Years	44-61	16	44-60	17	44-61	18	44-59	16
Check Hybrid 1		KE 1		Nodak. 201		Nodak. 201		Wisc. 416	
Test Period	Test Years	44-52	8	44-52	9	44-54	11	44-55	12
Period Compared	Years Compared	44-52	8	44-52	9	44-54	11	44-55	12
Hybrid 1 Yield / O-P Yield		109.8		100.7		98.3		112.7	
Check Hybrid 2		Nodak. 301		KE 1		Nodak. 208		Nodak. 301	
Test Period	Test Years	44-61	16	44-59	16	47-60	14	44-59	16
Period Compared	Years Compared	44-52	8	44-52	9	47-54	8	44-55	12
Hybrid 2 Yield / Hybrid 1 Yield		100.5		99.1		109.7		101.1	
Hybrid 2 Yield / O-P Yield		110.3		99.8		107.8		113.9	
Check Hybrid 3		Wisc. 240		Nodak. 301		Morden 77		Funk G 18	
Test Period	Test Years	44-58	12	44-61	18	49-60	12	47-59	13
Period Compared	Years Compared	44-58	12	44-59	16	49-60	12	47-59	13
Hybrid 3 Yield / Hybrid 2 Yield		93.3		104.3		92.1		107.7	
Hybrid 3 Yield / O-P Yield		102.9		104.1		99.3		122.7	
Check Hybrid 4		Nodak. 208		KE 7		Nodak. 306		KS 3	
Test Period	Test Years	47-60	13	51-61	11	54-61	8	50-61	12
Period Compared	Years Compared	47-58	10	51-61	11	54-60	7	50-59	10
Hybrid 4 Yield / Hybrid 3 Yield		106.9		99.0		105.9		99.8	
Hybrid 4 Yield / O-P Yield		110.0		103.1		105.2		122.5	
Check Hybrid 5		Morden 77		Nodak. 306		KC 3		Sokota 250	
Test Period	Test Years	49-61	12	54-61	8	54-61	8	55-61	7
Period Compared	Years Compared	49-60	11	54-61	8	54-61	8	55-61	7
Hybrid 5 Yield / Hybrid 4 Yield		92.2		103.3		92.8		98.8	
Hybrid 5 Yield / O-P Yield		101.4		106.5		97.6		121.0	

[a]Source: References; Corn, North Dakota.

Table B.14. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, North Carolina[a]

		Corn Test Districts									
		Northern Mountain		Western Mountain		Piedmont		Southern Coastal Area		Northern Coast. Area	
Relative Corn Acreage		.03		.05		.25		.30		.37	
Open-pollinated Varieties											
Test Period	Test Years	44-58	9	42-58	17	42-58	17	42-58	17	42-58	17
Check Hybrid 1		Funk G 94		U.S. 282		U.S. 282		Funk G 717		Funk G 717	
Test Period	Test Years	44-53	10	42-61	20	42-58	16	42-47	6	42-48	7
Period Compared	Years Compared	44-50	6	42-58	17	42-58	16	42-47	6	42-48	7
Hybrid 1 Yield /	O-P Yield	116.8		121.3		125.7		127.6		123.6	
Check Hybrid 2		U.S. 13		U.S. 13		N.C. 1032		Tenn. 10		Tenn. 10	
Test Period	Test Years	45-58	13	43-58	16	44-58	15	43-50	8	43-50	8
Period Compared	Years Compared	45-53	9	43-58	16	44-58	14	43-47	5	43-48	6
Hybrid 2 Yield /	Hybrid 1 Yield	103.7		97.8		97.4		101.2		100.6	
Hybrid 2 Yield /	O-P Yield	121.1		118.6		122.4		129.1		124.3	
Check Hybrid 3		Funk G 91		Funk G 134		Dixie 17		N.C. 27		N.C. 27	
Test Period	Test Years	52-61	9	51-61	10	46-58	13	46-61	15	46-61	15
Period Compared	Years Compared	52-58	6	51-58	7	46-58	13	46-50	5	46-50	5
Hybrid 3 Yield /	Hybrid 2 Yield	112.4		115.8		117.6		101.4		97.6	
Hybrid 3 Yield /	O-P Yield	136.1		137.4		143.9		130.9		121.3	
Check Hybrid 4		Wood V 264		V.P.I. 648		N.C. 27		Dixie 17		Dixie 17	
Test Period	Test Years	55-61	6	56-61	6	48-61	13	46-55	10	46-55	10
Period Compared	Years Compared	55-61	6	56-61	6	48-58	10	46-55	10	46-55	10
Hybrid 4 Yield /	Hybrid 3 Yield	94.1		101.5		95.3		109.5		114.8	
Hybrid 4 Yield /	O-P Yield	128.1		139.4		137.1		143.3		139.3	

[a]Source: References; Corn, North Carolina.

Table B.14 (Continued)

		Corn Test Districts							
		Northern Mountain	Western Mountain	Piedmont		Southern Coastal Area		Northern Coastal Area	
Check Hybrid 5				Dixie 82		Dixie 82		Dixie 82	
Test Period	Test Years			51-61	11	51-61	11	51-61	11
Period Compared	Years Compared			51-61	10	51-55	5	51-55	5
Hybrid 5 Yield /	Hybrid 4 Yield			103.4		97.3		102.3	
Hybrid 5 Yield /	O-P Yield			141.8		139.4		142.5	
Check Hybrid 6						Coker 911		Coker 911	
Test Period	Test Years					52-61	10	52-61	10
Period Compared	Years Compared					52-61	10	52-61	10
Hybrid 6 Yield /	Hybrid 5 Yield					103.3		98.8	
Hybrid 6 Yield /	O-P Yield					144.0		140.8	

Table B.15. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Ohio[a]

		Corn Test Districts			
		North		South	
Relative Corn Acreage		.60		.40	
Open-pollinated Varieties					
Test Period	Test Years	39-46	8	39-46	8
Check Hybrid 1		Ohio K-23		U.S. 360W	
Test Period	Test Years	39-45	7	39-44	6
Period Compared	Years Compared	39-45	7	39-44	6
Hybrid 1 Yield / O-P Yield		109.1		105.3	
Check Hybrid 2		Ohio M15		U.S. 13	
Test Period	Test Years	39-61	23	39-61	23
Period Compared	Years Compared	39-45	7	39-46	8
Hybrid 2 Yield / Hybrid 1 Yield		101.5		--	
Hybrid 2 Yield / O-P Yield		110.7		130.9	
Check Hybrid 3		Ohio K24		Ohio C38	
Test Period	Test Years	41-61	21	42-61	19
Period Compared	Years Compared	41-61	21	42-61	19
Hybrid 3 Yield / Hybrid 2 Yield		105.8		100.2	
Hybrid 3 Yield / O-P Yield		117.1		131.2	
Check Hybrid 4		Ohio W36		Ohio W36	
Test Period	Test Years	41-55	15	43-55	13
Period Compared	Years Compared	41-55	15	43-55	13
Hybrid 4 Yield / Hybrid 3 Yield		103.3		95.5	
Hybrid 4 Yield / O-P Yield		121.0		125.3	
Check Hybrid 5		Ohio C38		Mo 804	
Test Period	Test Years	41-55	15	51-57	5
Period Compared	Years Compared	41-55	15	51-57	5
Hybrid 5 Yield / Hybrid 4 Yield		103.8		114.5	
Hybrid 4 Yield / O-P Yield		125.6		149.9	
Check Hybrid 6		Iowa 4297		U.S. 523W	
Test Period	Test Years	49-60	8	57-61	4
Period Compared	Years Compared	49-55	6	57-61	4
Hybrid 6 Yield / Hybrid 5 Yield		94.6		113.5	
Hybrid 6 Yield / O-P Yield		118.8		148.6	
Check Hybrid 7		Ohio W64		AES 809	
Test Period	Test Years	49-61	8	58-61	4
Period Compared	Years Compared	49-55	6	58-61	4
Hybrid 7 Yield / Hybrid 6 Yield		106.3		113.3	
Hybrid 7 Yield / O-P Yield		126.3		148.3	

[a]Source: References; Corn, Ohio.

Table B.16. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Oklahoma[a]

		Corn Test Districts											
		Payne Upland				Garvin Bottom Land				Tulsa Bottom Land			
		Early		Late		Early		Late		Early		Late	
Relative Corn Acreage		Same for all districts.											
Open-pollinated Varieties													
Test Period	Test Years	43-47	5	43-55	11	44-47	3	44-55	9	44-47	4	44-53	10
Check Hybrid 1		Funk G 94		Texas 12		Key. 39		Texas 12		Shannon 1300		Funk G 711	
Test Period	Test Years	43-52	10	43-51	9	44-52	8	44-51	7	44-57	11	45-53	9
Period Compared	Years Compared	43-47	5	43-51	9	44-47	3	44-51	7	44-47	4	45-53	9
Hybrid 1 Yield /	O-P Yield	137.2		134.3		126.6		150.7		133.7		152.3	
Check Hybrid 2		Key. 38		Funk G 711		Key. 38		Funk G 711		Key. 38		Texas 28	
Test Period	Test Years	43-61	17	43-57	13	46-61	14	44-57	11	45-61	14	49-61	10
Period Compared	Years Compared	43-52	10	43-51	9	46-52	7	44-51	7	45-57	10	49-53	5
Hybrid 2 Yield /	Hybrid 1 Yield	105.8		117.5		103.3		102.0		124.7		103.7	
Hybrid 2 Yield /	O-P Yield	145.2		157.8		130.8		153.7		166.7		157.9	
Check Hybrid 3		Pioneer 300		Texas 28		Pioneer 300		Key. 222		Pioneer 300		Watson 111	
Test Period	Test Years	44-61	15	49-61	11	46-61	13	46-61	14	45-61	13	57-61	5
Period Compared	Years Compared	44-61	15	49-57	7	46-61	13	46-57	10	45-61	13	57-61	5
Hybrid 3 Yield /	Hybrid 2 Yield	102.0		106.6		101.3		100.0		100.9		114.1	
Hybrid 3 Yield /	O-P Yield	148.1		168.2		132.5		153.7		168.2		180.2	

[a]Source: References; Corn, Oklahoma.

Table B.16 (Continued)

		Corn Test Districts					
		Payne Upland		Garvin Bottom Land		Tulsa Bottom Land	
		Early	Late	Early	Late	Early	Late
Check Hybrid 4		AES 806	Texas 30	Key. 42	Texas 30	Key. 42	Texas 17W
Test Period	Test Years	55-61 6	51-61 9	48-59 10	51-61 9	48-59 9	57-61 5
Period Compared	Years Compared	55-61 6	51-61 9	48-59 10	51-61 9	48-59 9	57-61 5
Hybrid 4 Yield /	Hybrid 3 Yield	113.8	107.1	98.2	108.8	98.0	88.9
Hybrid 4 Yield /	O-P Yield	168.5	180.1	130.1	167.2	164.8	160.2
Check Hybrid 5		Funk G 144	Texas 17W	Okla. 1815	Texas 17W	Okla. 1815	
Test Period	Test Years	57-61 5	55-61 6	52-61 8	55-61 6	52-61 7	
Period Compared	Years Compared	57-61 5	55-61 6	52-59 6	55-61 6	52-59 5	
Hybrid 5 Yield /	Hybrid 4 Yield	100.7	106.5	126.7	103.8	119.3	
Hybrid 5 Yield /	O-P Yield	169.7	191.8	164.8	173.6	196.6	

Table B.17. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, South Dakota[a]

		Crop Districts 1, 2		3		4, 5, 7, 8		6		9	
Relative Corn Acreage		.13		.12		.21		.26		.28	
Open-pollinated Varieties											
Test Period	Test Years	45-54	10	37-47	10	45-48	4	37-47	11	37-45	9
Check Hybrid 1		Sokota 212		Pioneer 355		Sokota 224		Pioneer 822		Pioneer 322	
Test Period	Test Years	46-53	8	37-41	5	45-56	10	37-44	7	37-42	6
Period Compared	Years Compared	46-53	8	37-41	4	45-48	4	37-44	7	37-42	6
Hybrid 1 Yield /	O-P	115.7		121.8		113.9		109.0		116.2	
Check Hybrid 2		Sokota 250		Funks G 12		Sokota 400		K R 2		Funk G 29	
Test Period	Test Years	49-61	10	41-44	4	46-58	12	42-53	12	42-51	9
Period Compared	Years Compared	49-53	4	41-44	4	46-56	10	42-46	5	42-45	4
Hybrid 2 Yield /	Hybrid 1 Yield	106.4				110.9					
Hybrid 2 Yield /	O-P Yield	123.1		113.2		126.3		111.2		125.5	
Check Hybrid 3		Sokota 220		K S 6		Sokota 270		Sokota 400		Dekalb 410	
Test Period	Test Years	50-61	8	42-54	13	50-58	9	45-58	14	45-58	12
Period Compared	Years Compared	51-61	7	42-47	6	50-58	9	45-53	9	45-51	6
Hybrid 3 Yield /	Hybrid 2 Yield	94.8				100.7		103.0		110.2	
Hybrid 3 Yield /	O-P	116.7		118.4		127.2		114.5		138.3	
Check Hybrid 4		Pioneer 388		Sokota 400				Sokota 270		Pioneer 352	
Test Period	Test Years	51-61	9	46-58	13			50-58	9	50-59	9
Period Compared	Years Compared	51-61	8	46-54	9			50-58	9	50-58	8
Hybrid 4 Yield /	Hybrid 3 Yield	108.5		100.2				100.6		99.7	
Hybrid 4 Yield /	O-P Yield	126.6		118.6				115.2		137.9	

[a]Source: References; Corn, South Dakota.

Table B.17 (Continued)

		Crop Districts 1, 2	3		4, 5, 7, 8	6	9	
Check Hybrid 5			S D 250				Sokota 604	
Test Period	Test Years		49-61	11			54-61	7
Period Compared	Years Compared		49-58	10			54-59	6
Hybrid 5 Yield /	Hybrid 4 Yield		118.5				91.2	
Hybrid 5 Yield /	O-P Yield		140.5				125.8	
Check Hybrid 6			Pioneer 388				Sokota 622	
Test Period	Test Years		51-61	10			56-61	5
Period Compared	Years Compared		51-61	9			56-61	5
Hybrid 6 Yield /	Hybrid 5 Yield		94.6				114.2	
Hybrid 6 Yield /	O-P Yield		132.9				143.7	

Table B.18. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Tennessee[a]

		Corn Test Districts									
		1 and 2		3		4		5		6	
Relative Corn Acreage		.37		.18		.20		.11		.14	
Open-pollinated Varieties											
Test Period	Test Years	43-55	9	45-55	8	44-56	10	43-55	11	43-56	11
Check Hybrid 1		Tenn. 10		Tenn. 10		Tenn. 10		Tenn. 10		Tenn. 10	
Test Period	Test Years	43-55	10	45-55	9	44-55	9	43-55	12	43-55	11
Period Compared	Years Compared	43-55	9	45-55	8	44-55	8	43-55	11	43-55	11
Hybrid 1 Yield / O-P Yield		105.4		110.4		117.3		112.6		114.3	
Check Hybrid 2		Funk G 711		Funk G 711		Funk G 711		Funk G 711		Funk G 711	
Test Period	Test Years	47-59	12	46-57	10	44-59	13	45-57	12	46-59	13
Period Compared	Years Compared	47-59	11	46-57	9	44-59	12	45-57	11	46-59	13
Hybrid 2 Yield / Hybrid 1 Yield		102.3		96.2		92.2		92.0		97.6	
Hybrid 2 Yield / O-P Yield		107.8		106.2		108.2		103.6		111.6	
Check Hybrid 3		Dixie 22		Dixie 22		Dixie 22		Dixie 22		Dixie 22	
Test Period	Test Years	47-61	14	46-57	10	47-60	13	46-57	12	46-60	15
Period Compared	Years Compared	47-61	13	46-57	9	47-60	12	46-57	10	46-60	14
Hybrid 3 Yield / Hybrid 2 Yield		102.5		101.1		101.4		108.0		102.8	
Hybrid 3 Yield / O-P Yield		110.5		107.4		109.7		111.9		114.7	
Check Hybrid 4		Dixie 29		Dixie 29		Dixie 29		Dixie 29		Dixie 29	
Test Period	Test Years	51-61	10	51-61	10	51-61	10	51-61	11	51-61	11
Period Compared	Years Compared	51-61	9	51-61	9	51-60	9	51-61	9	51-61	10
Hybrid 4 Yield / Hybrid 3 Yield		104.7	106.9	106.9		117.7		101.8		105.8	
Hybrid 4 Yield / O-P Yield		115.7		114.8		129.1		113.9		121.4	
Check Hybrid 5		Pion. 309A		Pion. 309A		Pion. 309A		Pion. 309A		Pion. 309A	
Period Compared	Years Compared	55-61	7	55-61	7	55-61	7	55-61	7	55-61	7
Test Period	Test Years	55-61	7	55-61	7	55-61	7	55-61	7	55-61	7
Hybrid 5 Yield / Hybrid 4 Yield		90.4		82.5		90.2		92.7		91.1	
Hybrid 5 Yield / O-P Yield		104.6		94.7		116.4		105.6		110.6	

[a]Source: References; Corn, Tennessee.

Table B.19. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Texas[a]

		Corn Test Districts									
		1		2		3		4		5	
Relative Corn Acreage		.10		.15		.30		.40		.05	
Open-pollinated Varieties											
Test Period	Test Years	41-61	19	41-61	19	41-61	19	41-61	19	41-61	17
Check Hybrid 1		Texas 8		Texas 8		Texas 8		Texas 8		Texas 8	
Test Period	Test Years	41-50	10	41-50	10	41-53	13	41-53	13	41-52	12
Period Compared	Years Compared	41-50	10	41-50	10	41-53	13	41-53	13	41-52	12
Hybrid 1 Yield /	O-P Yield	121.5		130.7		130.7		160.5		136.1	
Check Hybrid 2		Texas 12		Texas 12		Funk G 711		Funk G 711		Funk G 711	
Test Period	Test Years	41-50	10	41-50	10	42-56	15	42-56	15	42-55	14
Period Compared	Years Compared	41-50	10	41-50	10	42-53	12	42-53	12	42-52	11
Hybrid 2 Yield /	Hybrid 1 Yield	108.4		111.6		96.8		88.9		98.4	
Hybrid 2 Yield /	O-P Yield	131.7		145.9		126.5		142.7		133.9	
Check Hybrid 3		Texas 26		Funk G 711		United U72		United U72		Texas 26	
Test Period	Test Years	45-56	11	43-56	13	45-56	12	45-56	12	45-55	9
Period Compared	Years Compared	45-50	6	43-50	8	45-56	12	45-56	12	45-55	9
Hybrid 3 Yield /	Hybrid 2 Yield	105.3		102.0		102.9		120.9		113.2	
Hybrid 3 Yield /	O-P	138.7		148.8		130.2		172.5		151.6	
Check Hybrid 4		Texas 28		Texas 28		Texas 28		Texas 28		Texas 28	
Test Period	Test Years	47-61	13	48-61	11	47-61	13	47-61	13	47-61	11
Period Compared	Years Compared	47-56	9	48-56	9	47-56	10	47-56	10	47-55	7
Hybrid 4 Yield /	Hybrid 3 Yield	102.5		120.4		114.8		114.3		97.0	
Hybrid 4 Yield /	O-P Yield	142.2		179.2		149.5		197.2		147.1	
Check Hybrid 5		Texas 30		Texas 30		Texas 30		Texas 30		Texas 30	
Test Period	Test Years	49-61	11	50-61	9	49-61	11	51-61	9	52-61	6
Period Compared	Years Compared	49-61	11	50-61	10	49-61	11	51-61	9	52-61	6
Hybrid 5 Yield /	Hybrid 4 Yield	99.4		101.2		98.0		89.8		103.5	
Hybrid 5 Yield /	O-P Yield	141.3		181.4		146.5		177.1		152.2	

[a]Source: References; Corn, Texas.

Table B.20. Yield comparisons of check hybrids and open-pollinated varieties in corn yield tests, Wisconsin[a]

		Corn Test Districts Up to Mat. Gr. 105		Mat. Group 110-112		Mat. Group 115-120	
Relative Corn Acreage		.60		.20		.20	
Open-pollinated Varieties							
Test Period	Test Years	37-43	7	37-44	8	37-44	8
Check Hybrid 1		W 570		W 570		W 570	
Test Period	Test Years	37-40	4	37-42	5	37-42	5
Period Compared	Years Compared	37-40	4	37-42	5	37-42	5
Hybrid 1 Yield /	O-P Yield	121.0		118.3		115.9	
Check Hybrid 2		W 606		W 606		W 606	
Test Period	Test Years	37-49	12	37-49	13	37-49	13
Period Compared	Years Compared	37-43	6	37-42	5	37-40	4
Hybrid 2 Yield /	Hybrid 1 Yield	--		--		104.7	
Hybrid 2 Yield /	O-P Yield	120.2		119.5		121.3	
Check Hybrid 3		W 595		W 595		W 595	
Test Period	Test Years	45-52	8	44-52	9	44-52	9
Period Compared	Years Compared	45-49	5	44-49	6	44-52	9
Hybrid 3 Yield /	Hybrid 2 Yield	110.1		113.4		114.0	
Hybrid 3 Yield /	O-P Yield	132.3		135.5		138.3	
Check Hybrid 4		W 575		W 575		W 575	
Test Period	Test Years	50-61	12	50-61	12	50-61	12
Period Compared	Years Compared	50-52	3	50-52	3	50-52	3
Hybrid 4 Yield /	Hybrid 3 Yield	106.9		107.5		107.0	
Hybrid 4 Yield /	O-P Yield	141.4		145.7		148.0	
Check Hybrid 5		W 613		W 613		W 613	
Test Period	Test Years	54-61	8	54-61	8	54-61	8
Period Compared	Years Compared	54-61	8	54-61	8	54-61	8
Hybrid 5 Yield /	Hybrid 4 Yield	105.1		106.3		106.1	
Hybrid 5 Yield /	O-P Yield	148.6		154.9		157.0	
Check Hybrid 6		W 563		W 563		W 563	
Test Period	Test Years	56-61	6	56-61	8	56-61	6
Period Compared	Years Compared	56-61	6	56-61	6	56-61	6
Hybrid 6 Yield /	Hybrid 5 Yield	98.1		98.4		99.1	
Hybrid 6 Yield /	O-P Yield	145.8		152.4		155.6	

[a]Source: References; Corn, Wisconsin.

Table B.21. Characteristics of linear regressions of average corn test yields on years by states[a]

Region	State	Period of Years	b_o	b_1	r^2
		(1)	(2)	(3)	(4)
Lake States	Michigan	1938-61	3.63	1.39**	.52
	Wisconsin	1937-61	-51.87	3.07**	.79
	Minnesota	1937-61	-11.80	1.81**	.59
Corn Belt	Ohio	1939-61	28.48	1.21**	.30
	Indiana	1937-61	37.26	.97*	.25
	Illinois	1934-61	10.67	1.46**	.52
	Iowa	1926-61	18.94	1.37**	.65
	Missouri	1937-61	-13.25	1.84**	.58
N. Plains	N. Dakota	1944-61	12.18	.67*	.24
	S. Dakota	1937-61	12.74	.71+	.14
	Nebraska	1937-61	-4.92	1.34**	.30
	Kansas	1939-61	-21.48	1.75*	.26
S. Plains	Texas	1941-61	-3.23	.86*	.24
	Oklahoma	1943-61	25.36	.55+	.19
Delta States	Arkansas	1941-61	-100.26	2.99**	.51
	Mississippi	1943-61	3.24	1.06*	.28

[a]Source: References; Corn.

**Tested statistically significant at the one percent level.

*Tested statistically significant at the five percent level.

+Tested statistically significant at the ten percent level.

XII. APPENDIX C

Table C.1. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Arkansas, 1939 to 1961

	NPK Application per Acre					Percent
Years	Corn lbs.	Cotton lbs.	Soybeans lbs.	T. Hay lbs.	Rice lbs.	of State Consumption
1939	3.5	8.6				88.3
1940	6.6	13.6				85.9
1941	7.9	14.6				83.4
1942	7.8	14.7				81.0
1943	11.5	20.2				78.6
1944	12.3	20.0				76.2
1945	12.3	17.8	1.3	1.3	1.4	75.9
1946	15.1	18.0	2.2	2.4	3.2	76.1
1947	17.4	18.8	3.6	3.7	4.3	75.6
1948	18.5	18.4	4.4	4.5	5.3	75.6
1949	25.6	24.2	7.2	7.2	7.8	75.2
1950	33.8	29.4	8.5	9.3	12.1	76.1
1951	36.9	49.1	8.1	8.5	23.5	79.5
1952	31.8	55.1	6.2	5.8	27.3	82.2
1953	29.7	66.0	4.4	3.8	35.0	85.6
1954	32.4	85.3	3.2	2.2	47.2	88.9
1955	34.0	94.3	4.3	2.5	55.0	88.9
1956	40.2	117.0	6.3	3.2	69.8	88.4
1957	42.2	128.0	7.5	3.5	78.5	88.7
1958	40.1	125.8	8.1	3.6	78.5	88.5
1959	40.6	132.0	9.3	3.9	83.3	88.6
1960	41.1	136.7	10.6	4.2	86.3	88.4
1961	40.5	138.0	11.3	4.3	87.8	88.4

Table C.2. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Illinois, 1939 to 1961

	NPK Application per Acre					Percent
	Corn	Wheat	Oats	Soybeans	T. Hay	of State
Years	lbs.	lbs.	lbs.	lbs.	lbs.	Consumption
1939	1.8	2.3	.7	.2		97.4
1940	2.2	2.9	1.0	.3		96.8
1941	2.9	4.0	1.6	.5		96.2
1942	4.6	6.4	2.8	.8		95.7
1943	5.1	7.1	3.2	.9		95.2
1944	5.2	7.3	3.4	1.0		94.6
1945	8.3	13.7	4.6	1.2		94.2
1946	10.8	19.2	5.4	1.3		93.7
1947	14.7	27.5	6.8	1.5		93.2
1948	16.1	31.0	7.1	1.5		92.8
1949	17.4	33.8	7.5	1.5		92.3
1950	18.5	36.3	7.8	1.5		91.8
1951	22.6	47.5	13.5	3.1	2.8	91.7
1952	29.2	64.0	21.0	5.3	6.1	91.6
1953	35.3	75.1	26.6	6.8	8.9	91.5
1954	38.4	83.8	31.3	8.2	11.4	91.5
1955	37.6	73.6	23.7	7.6	8.9	92.0
1956	40.7	71.4	19.2	7.8	7.6	92.6
1957	48.5	76.3	16.4	8.8	7.1	93.1
1958	55.8	78.6	12.5	9.5	6.2	93.7
1959	63.2	79.8	8.1	10.0	5.0	94.3
1960	59.7	70.3	3.1	9.3	3.5	94.8
1961	75.3	77.0	1.2	10.3	2.7	95.6

Table C.3. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Indiana, 1939 to 1961

Years	NPK Application per Acre Corn lbs.	Wheat lbs.	Oats lbs.	Soybeans lbs.	T. Hay lbs.	Percent of State Consumption
1939	11.3	21.2	2.8	1.1	2.2	90.8
1940	17.2	28.8	5.5	2.9	3.6	90.2
1941	16.4	24.9	6.2	3.6	3.5	89.7
1942	21.0	28.8	8.8	5.6	4.7	89.1
1943	23.5	30.2	10.8	7.1	5.3	88.6
1944	22.4	26.9	11.0	7.3	5.2	88.0
1945	25.9	31.8	13.6	9.5	5.2	88.4
1946	31.3	39.4	17.3	12.2	5.6	88.8
1947	33.2	42.8	19.3	13.6	5.4	89.2
1948	38.1	49.9	22.8	16.2	5.7	89.5
1949	41.4	54.0	25.1	18.4	5.6	89.9
1950	45.5	59.8	27.9	20.4	5.6	90.4
1951	58.9	67.7	38.3	21.0	7.4	90.9
1952	70.8	74.2	47.6	20.7	9.0	91.5
1953	84.2	82.2	58.0	20.9	10.8	92.1
1954	94.0	86.4	66.2	20.5	12.2	92.6
1955	101.5	92.7	66.2	21.8	13.1	92.7
1956	102.5	93.2	61.9	21.6	13.0	92.8
1957	114.3	103.6	63.9	23.5	14.2	93.0
1958	119.3	108.0	61.5	23.6	14.5	93.1
1959	122.4	110.6	58.1	23.0	14.6	93.4
1960	121.7	109.5	53.4	22.1	14.3	93.6
1961	138.9	124.4	56.4	24.1	16.2	93.8

Table C.4. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Iowa, 1939 to 1961

	NPK Application per Acre						
Years	Corn lbs.	Wheat lbs.	Oats lbs.	Soybeans lbs.	T. Hay lbs.	Pasture lbs.	Percent of State Consumption
1939	.5	.5	.2			.0	94.3
1940	.6	.6	.3			.0	93.2
1941	.9	1.0	.5			.0	92.0
1942	1.4	1.6	.9			.1	90.9
1943	1.7	2.0	1.1			.1	89.8
1944	2.0	2.2	1.3			.1	88.7
1945	3.3	4.0	3.2	.2	.7	.2	89.8
1946	4.0	4.9	4.6	.3	1.4	.2	90.9
1947	5.0	5.6	5.8	.5	1.9	.2	92.0
1948	6.2	7.0	7.7	.6	2.7	.3	93.1
1949	7.7	8.3	9.4	.8	3.5	.3	94.1
1950	7.4	8.4	9.6	.9	3.7	.3	95.4
1951	11.1	12.4	10.1	1.3	3.3	.6	96.3
1952	13.6	14.8	9.9	1.5	2.8	.7	97.3
1953	19.9	21.3	12.4	2.1	3.2	1.1	98.3
1954	29.9	31.4	15.9	2.9	3.5	1.5	99.4
1955	30.3	25.2	13.1	2.3	3.5	1.4	99.4
1956	26.1	16.7	9.3	1.6	3.1	1.1	99.4
1957	28.2	13.6	7.6	1.2	3.1	1.1	99.3
1958	35.1	12.4	6.9	.9	3.6	1.2	99.3
1959	40.1	9.3	5.3	.4	3.8	1.2	99.3
1960	41.8	5.3	3.1	.0[a]	3.7	1.1	99.2
1961	57.5	5.6	1.5	.0	4.4	1.3	99.2

[a]Less than .05 pounds per acre.

Table C.5. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Kansas, 1939 to 1961

Years	NPK Application per Acre Corn lbs.	Wheat lbs.	Oats lbs.	Barley lbs.	T. Hay lbs.	G. Sorghum lbs.	Percent of State Consumption
1939	.1	.6	.8				96.4
1940	.2	.8	.9				93.4
1941	.1	.7	.7				90.4
1942	.1	1.1	.9				87.4
1943	.1	1.3	.9				84.4
1944	.1	1.1	.7				81.4
1945	.1	1.2	1.2	.3	1.5	.0[a]	84.2
1946	.1	1.1	1.2	.4	1.9	.0[a]	87.0
1947	.2	1.6	1.9	.7	3.2	.1	89.4
1948	.3	2.4	3.0	1.3	5.3	.2	91.8
1949	.4	2.7	3.4	1.4	6.5	.2	94.6
1950	.8	5.0	6.8	3.1	11.6	.4	96.4
1951	4.2	6.8	12.1	6.0	12.0	1.0	95.2
1952	5.6	5.5	11.8	6.2	6.7	1.1	93.7
1953	10.7	8.0	19.4	10.5	6.3	1.8	92.5
1954	12.2	7.6	19.9	10.8	3.3	2.0	91.4
1955	15.3	9.1	22.5	12.0	4.0	3.5	91.8
1956	15.1	8.5	20.5	10.9	3.8	4.0	92.2
1957	17.8	9.6	22.3	11.6	4.4	5.3	92.5
1958	14.7	7.8	17.0	8.7	3.5	4.9	93.0
1959	20.6	10.6	22.1	11.2	4.8	7.5	93.4
1960	25.4	12.7	25.7	12.8	5.8	9.8	93.8
1961	35.3	17.5	33.9	16.8	8.0	14.5	94.3

[a]Less than .05 pounds per acre.

Table C.6. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Louisiana, 1939 to 1961

	NPK Application per Acre							Percent
	Corn	Cotton	Oats	Soybeans	T. Hay	Rice	S. Cane	of State
Years	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	Consumption
1939	3.8	20.2	9.3		.2	9.3	25.8	67.2
1940	4.7	17.2	7.9		.4	8.4	21.5	63.9
1941	7.4	20.2	9.1		.7	10.7	24.2	60.7
1942	7.7	17.3	6.8		.8	10.4	18.8	57.4
1943	10.1	19.0	7.1		1.1	12.2	19.5	54.2
1944	12.5	18.8	8.6		1.4	11.8	21.2	50.9
1945	13.5	18.5	12.8	2.5	2.4	12.7	20.5	52.5
1946	17.8	23.7	19.2	6.1	4.2	18.2	24.3	53.6
1947	19.4	24.0	23.2	8.8	5.4	19.7	24.7	54.9
1948	20.6	24.3	27.0	10.3	6.0	20.4	25.0	56.4
1949	22.0	25.2	30.9	11.8	6.6	21.8	25.6	57.6
1950	30.5	32.7	45.4	14.9	8.1	28.2	34.1	60.5
1951	35.9	45.6	45.1	11.6	8.6	34.2	44.2	64.2
1952	39.8	57.3	42.9	8.0	9.0	39.7	52.4	67.8
1953	38.3	60.7	36.3	3.8	8.4	40.7	52.3	70.7
1954	47.8	79.2	38.3	.0	8.8	47.8	69.9	75.4
1955	54.8	89.0	44.4	1.7	10.3	59.4	80.9	75.7
1956	59.2	95.0	48.7	3.7	11.8	71.0	85.9	75.1
1957	52.2	83.3	43.0	5.6	11.7	73.4	69.0	73.3
1958	69.7	108.3	58.5	7.2	13.9	90.6	104.4	75.4
1959	63.7	97.8	53.6	8.1	13.1	87.9	94.0	75.1
1960	69.2	105.0	58.4	10.2	14.5	99.5	101.6	74.8
1961	71.2	106.7	59.7	12.1	15.2	107.2	102.6	74.5

Table C.7. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Michigan, 1939 to 1961

Years	Corn lbs.	Wheat lbs.	Oats lbs.	Soybeans lbs.	T. Hay lbs.	Potatoes lbs.	Barley lbs.	S. Beets lbs.	D. Beans lbs.	Percent of State Consumption
				NPK Application per Acre						
1939	6.3	19.8	8.2	1.2	1.1	55.4	15.3	36.1	6.9	92.0
1940	7.5	20.4	9.7	2.4	1.2	64.4	16.1	37.1	8.3	90.2
1941	9.4	22.8	12.1	3.8	1.4	78.1	18.4	41.4	10.4	88.4
1942	13.4	29.6	16.9	6.3	1.9	110.8	24.6	54.1	15.0	86.5
1943	12.4	25.2	15.7	6.5	1.7	101.5	21.2	46.0	13.9	84.7
1944	13.1	24.7	16.5	7.3	1.7	106.6	21.0	45.2	14.5	82.9
1945	13.8	27.3	16.7	9.9	2.8	122.3	24.2	51.3	18.0	80.1
1946	15.0	30.6	17.4	12.9	4.1	138.9	28.0	59.7	22.0	77.4
1947	15.7	33.1	17.6	15.7	5.3	153.2	31.2	66.9	25.6	74.6
1948	14.6	31.6	15.7	16.3	5.7	149.3	30.5	65.2	25.8	71.8
1949	16.1	35.9	16.7	19.8	7.1	173.9	35.4	73.4	30.5	69.0
1950	17.1	39.1	17.2	22.8	8.4	192.3	39.2	80.9	34.5	66.1
1951	26.4	46.8	25.4	21.3	7.9	213.2	41.0	97.3	34.0	70.7
1952	37.1	56.7	34.8	20.4	7.5	244.7	44.7	119.6	34.9	75.3
1953	47.7	66.4	44.1	19.4	7.1	275.1	48.0	140.5	35.5	80.2
1954	58.0	75.1	52.8	18.0	6.5	302.8	50.6	159.3	35.5	85.1
1955	67.7	83.5	59.0	22.1	7.4	310.9	56.0	185.7	42.5	85.6
1956	72.7	85.9	61.0	24.7	7.7	298.2	57.4	198.4	46.4	86.0
1957	82.7	93.2	66.3	28.4	8.5	303.6	62.1	222.9	52.7	86.4
1958	84.1	92.2	65.9	29.8	8.4	281.1	61.2	226.7	54.6	86.9
1959	95.7	101.6	72.7	34.3	9.4	291.9	67.2	256.3	62.2	87.2
1960	94.8	98.1	70.4	34.5	9.1	265.9	64.7	253.1	62.0	87.6
1961	111.0	109.8	78.4	39.2	10.6	284.3	72.0	290.4	70.1	87.9

Table C.8. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Minnesota, 1939 to 1961

	NPK Application per Acre									
Years	Corn lbs.	Wheat lbs.	Oats lbs.	Soybeans lbs.	T. Hay lbs.	Potatoes lbs.	Barley lbs.	S. Beets lbs.	Flax lbs.	Percent of State Consumption
1939	.6	.4	.3		.3	4.3	.3	5.4	.4	98.8
1940	.9	.7	.4		.5	4.3	.4	5.9	.6	97.8
1941	1.5	1.3	.6		.9	5.6	.6	8.5	1.1	96.9
1942	1.9	1.7	.7		1.2	6.3	.7	9.4	1.4	95.8
1943	2.0	1.9	.8		1.5	6.5	.8	9.4	1.6	94.8
1944	2.7	2.5	1.0		1.8	7.6	1.0	11.0	2.1	93.7
1945	3.5	3.3	1.3		2.5	9.6	1.3	13.9	2.8	92.6
1946	6.2	5.6	2.2		4.1	14.6	2.2	22.6	4.8	91.7
1947	6.1	6.2	2.2		4.4	15.5	2.3	21.5	5.1	90.3
1948	8.7	8.4	3.1		6.0	20.0	3.1	29.5	7.1	89.2
1949	10.6	10.3	3.8		7.7	24.4	3.8	36.1	8.7	88.3
1950	10.4	10.3	3.7		7.8	23.9	3.8	34.7	8.7	87.2
1951	11.3	7.4	3.5	1.6	6.3	31.9	3.1	31.0	6.5	87.1
1952	14.2	6.7	4.0	3.1	6.0	44.3	3.1	33.1	6.1	87.4
1953	17.7	6.0	4.6	4.9	5.9	58.7	3.3	36.5	5.7	87.9
1954	24.5	6.2	6.0	7.5	6.2	84.0	4.0	44.4	6.3	88.9
1955	31.2	11.8	5.7	7.6	7.3	104.1	5.2	90.5	5.5	89.9
1956	33.2	15.0	4.6	6.9	7.8	110.1	5.4	126.4	3.7	90.6
1957	40.2	21.2	4.3	7.1	9.2	132.3	6.6	184.7	2.7	91.4
1958	43.5	24.9	3.4	6.2	9.0	137.3	7.2	208.7	1.3	92.4
1959	47.7	28.8	2.7	5.8	9.8	150.4	7.7	244.5		93.1
1960	47.1	30.9	1.8	5.4	10.0	151.3	7.6	281.1		93.8
1961	56.5	37.3	1.3	5.4	11.2	177.0	9.0	322.7		94.6

Table C.9. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Mississippi, 1939 to 1961

	NPK Application per Acre						Percent
Years	Corn lbs.	Cotton lbs.	Oats lbs.	Soybeans lbs.	T. Hay lbs.	Rice lbs.	of State Consumption
1939	10.3	25.2	5.8	.7	1.7		87.7
1940	12.5	23.6	10.4	1.3	2.4		87.5
1941	15.8	24.2	15.6	2.0	3.2		87.2
1942	19.1	26.5	18.0	3.3	4.9		86.9
1943	28.3	32.9	29.4	5.1	7.3		86.7
1944	30.0	30.1	32.8	5.7	7.9		86.4
1945	28.0	33.1	30.7	5.4	8.2		84.4
1946	32.1	42.7	35.9	6.1	10.4		81.8
1947	29.4	42.5	36.1	4.9	8.8		80.2
1948	32.4	50.2	41.4	5.1	9.8		77.5
1949	37.2	58.6	52.5	4.7	9.1		76.3
1950	42.0	66.1	64.3	4.1	7.7		76.5
1951	50.5	79.2	57.8	4.9	9.0	18.0	78.1
1952	56.3	86.8	48.0	5.5	10.0	33.7	80.1
1953	55.0	84.1	37.3	4.6	8.4	47.0	83.8
1954	68.3	104.0	34.6	5.5	9.7	71.1	86.1
1955	75.7	111.6	34.9	4.5	10.3	73.4	86.1
1956	85.9	120.6	35.5	4.2	12.6	72.0	85.3
1957	101.8	139.3	39.0	3.5	14.2	80.1	85.3
1958	100.0	133.7	35.9	2.3	13.4	74.1	85.2
1959	103.1	131.6	32.7	1.8	15.9	64.1	83.9
1960	110.5	138.1	32.5	1.1	17.0	63.1	83.6
1961	112.7	137.6	30.8	.5	17.7	59.1	83.2

Table C.10. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Missouri, 1939 to 1961

	NPK Application per Acre						
Years	Corn lbs.	Wheat lbs.	Oats lbs.	Soybeans lbs.	T. Hay lbs.	Barley lbs.	Percent of State Consumption
1939	1.1	6.5	3.1	.3	1.1	4.2	97.0
1940	1.4	7.0	3.7	.5	1.9	5.1	96.1
1941	1.6	7.1	4.1	.7	2.6	5.6	95.3
1942	2.2	8.9	5.7	1.1	4.1	7.6	94.4
1943	2.6	10.0	6.7	1.5	5.2	8.9	93.6
1944	3.0	10.6	7.5	1.8	6.2	9.9	92.7
1945	3.9	13.6	8.3	1.5	5.1	14.1	90.8
1946	5.1	18.0	10.1	1.5	5.0	20.0	89.0
1947	7.9	25.4	13.3	1.6	5.0	29.0	86.5
1948	8.4	26.5	13.2	1.4	3.9	30.8	84.2
1949	10.5	32.9	15.9	1.4	3.7	39.0	81.6
1950	12.5	37.7	17.7	1.3	3.3	45.1	78.9
1951	25.8	48.4	25.6	2.8	4.4	54.9	78.6
1952	36.3	48.7	28.4	3.8	4.6	52.2	78.6
1953	45.4	46.5	29.7	4.6	4.7	46.9	78.8
1954	50.9	42.0	29.0	4.8	4.6	39.8	79.2
1955	47.6	36.1	25.8	4.2	4.0	34.0	78.1
1956	51.9	37.1	27.2	4.3	4.2	34.5	76.9
1957	63.3	40.7	31.1	4.6	4.8	38.1	75.7
1958	65.2	38.0	30.5	4.3	4.7	35.9	74.4
1959	70.4	39.5	32.2	4.4	4.9	36.5	73.2
1960	71.2	38.5	31.9	4.3	4.9	35.9	72.0
1961	94.0	45.5	39.3	4.8	6.0	44.2	70.6

Table C.11. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Nebraska, 1939 to 1961

	NPK Application per Acre							Percent
Years	Corn lbs.	Wheat lbs.	Oats lbs.	S. Beets lbs.	T. Hay lbs.	G. Sorghum lbs.	Barley lbs.	of State Consumption
1939	.0[a]	.0[a]		15.4	.2			81.1
1940	.0[a]	.0[a]		13.1	.3			78.1
1941	.0[a]	.0[a]		9.7	.3			75.1
1942	.0[a]	.1		9.0	.3			72.1
1943	.0[a]	.0[a]		6.6	.3			69.7
1944	.0[a]	.0[a]		5.0	.2			65.6
1945	.1	.1		6.1	.3			69.5
1946	.3	.1		7.8	.4			76.6
1947	.6	.2		11.8	.7			73.2
1948	1.1	.2		15.4	.9			77.1
1949	1.6	.4		22.3	1.3			75.7
1950	2.3	.4		23.2	1.3			75.9
1951	3.3	.9	1.0	16.7	.8	.4	.4	78.4
1952	5.2	1.6	2.0	20.9	.9	.7	.8	81.1
1953	9.1	2.8	3.6	27.5	1.0	1.3	1.5	87.2
1954	15.5	4.9	6.5	40.6	1.4	2.4	2.6	91.0
1955	18.8	5.6	6.7	52.3	1.4	4.1	3.0	91.9
1956	17.0	4.6	5.1	44.0	1.0	4.6	2.5	93.4
1957	22.5	6.0	6.2	62.0	1.2	6.8	3.2	94.2
1958	28.9	7.1	6.7	71.3	1.2	9.7	3.8	95.5
1959	33.0	8.0	7.1	84.4	1.2	11.7	4.2	96.3
1960	34.0	8.1	6.9	89.6	1.2	12.7	4.3	97.1
1961	62.7	14.5	12.0	166.1	2.0	36.7	7.8	97.8

[a]Less than .05 pounds per acre.

Table C.12. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, North Dakota, 1939 to 1961

Years	Corn lbs.	Wheat lbs.	NPK Application per Acre Oats lbs.	Potatoes lbs.	T. Hay lbs.	Flax lbs.	Barley lbs.	S. Beets lbs.	Percent of State Consumption
1939	.2	.0[a]		1.5	.0		.0[a]	6.1	99.4
1940	.3	.0[a]		2.3	.1		.1	7.3	99.0
1941	.4	.0[a]		2.6	.1		.1	7.0	98.6
1942	.5	.1		2.9	.1		.1	7.1	98.1
1943	.5	.1		3.4	.1		.1	7.8	97.8
1944	.3	.0[a]		3.2	.9		.1	6.6	97.7
1945	.8	.1		7.6	.2		.1	15.0	97.4
1946	.8	.1		11.4	.2		.1	21.2	97.5
1947	1.9	.2		21.4	.4		.2	39.3	97.1
1948	3.8	.3		35.1	.9		.5	63.9	96.4
1949	3.4	.3		32.1	.8		.4	57.1	96.2
1950	3.3	.3		29.0	.8		.4	51.0	95.7
1951	1.7	.4	.1	26.0	.4	.0	.6	40.8	96.2
1952	2.9	1.1	.4	43.5	.5	.1	1.6	64.4	96.5
1953	2.9	1.7	.6	40.9	.5	.2	2.3	62.0	96.8
1954	2.9	2.2	.8	43.3	.4	.3	3.0	63.0	97.2
1955	3.4	3.5	1.2	47.2	.5	.3	4.0	65.3	97.4
1956	3.7	4.6	1.6	49.6	.6	.4	4.7	64.1	97.6
1957	4.0	5.7	1.9	54.7	.6	.4	5.6	64.0	97.9
1958	5.0	7.6	2.6	61.5	.8	.5	7.2	70.9	98.1
1959	6.1	9.7	3.3	71.1	1.0	.6	9.1	78.6	98.3
1960	6.7	11.1	3.8	76.2	1.1	.7	10.3	81.0	98.5
1961	8.8	14.8	5.1	99.2	1.4	.9	13.8	100.2	98.7

[a]Less than .05 pounds per acre.

Table C.13. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Ohio, 1939 to 1961

	NPK Application per Acre						Percent
Years	Corn lbs.	Wheat lbs.	Oats lbs.	Soybeans lbs.	T. Hay lbs.	Potatoes lbs.	of State Consumption
1939	14.3	30.6	12.6	2.5	1.5	99.2	90.7
1940	16.5	31.1	14.6	3.0	1.9	104.9	89.8
1941	19.1	32.5	17.0	3.5	2.4	113.6	88.9
1942	22.7	35.6	20.5	4.3	2.9	126.0	87.9
1943	26.2	38.0	23.6	5.0	3.5	138.6	87.0
1944	26.1	35.6	23.4	5.0	3.6	134.0	86.1
1945	31.6	40.4	25.6	5.7	3.8	170.5	85.9
1946	34.9	42.5	26.3	6.1	3.8	193.8	85.6
1947	41.8	48.9	29.7	7.2	4.2	236.5	85.4
1948	42.5	48.1	28.6	7.2	3.9	245.5	85.1
1949	48.9	53.7	31.2	8.2	4.2	287.8	84.8
1950	55.2	59.0	33.5	9.0	4.5	330.0	84.6
1951	62.6	65.6	40.2	9.7	5.7	288.0	85.2
1952	67.5	69.6	45.3	9.8	6.7	234.9	86.0
1953	78.1	79.6	54.4	10.6	8.2	201.5	86.7
1954	83.0	83.8	59.5	10.7	9.2	152.1	87.4
1955	94.9	87.4	62.1	12.0	10.1	165.2	88.0
1956	99.7	84.7	60.2	12.3	10.3	167.5	88.6
1957	113.6	89.5	63.6	13.5	11.2	184.7	89.1
1958	120.0	88.2	62.6	13.9	11.4	189.1	89.8
1959	123.1	84.6	59.9	13.8	11.2	187.2	90.4
1960	130.0	84.1	59.6	14.3	11.6	192.9	91.1
1961	137.1	83.1	58.2	14.5	11.4	191.3	91.8

Table C.14. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Oklahoma, 1939 to 1961

Years	NPK Application per Acre Corn lbs.	 Wheat lbs.	 Oats lbs.	 Cotton lbs.	 T. Hay lbs.	 G. Sorghum lbs.	 Barley lbs.	Percent of State Consumption
1939	.3			.2				30.7
1940	.1			.2				30.7
1941	.2			.3				30.7
1942	.3			.6				30.7
1943	.3			.9				30.7
1944	.5	.1	.3	.5	.5		.2	36.7
1945	.6	.2	.4	.5	.7		.3	42.8
1946	1.1	.3	.7	.8	1.2		.5	48.8
1947	1.7	.4	1.0	1.1	1.7		1.1	54.9
1948	3.0	.7	1.8	1.9	3.0		1.8	60.9
1949	5.2	1.2	3.0	3.2	5.2		3.4	67.0
1950	9.3	2.2	5.5	5.6	9.9		5.8	72.9
1951	11.1	2.5	6.1	5.8	7.8	.5	4.1	71.6
1952	15.0	3.1	7.5	7.0	6.2	1.1	4.2	70.4
1953	17.2	3.5	8.1	7.2	4.5	1.5	3.7	69.4
1954	21.7	4.5	9.9	8.2	3.3	2.2	3.6	68.8
1955	23.1	5.2	10.5	9.8	3.9	2.8	3.6	68.5
1956	23.0	5.6	10.6	10.8	4.3	3.2	3.4	67.9
1957	21.3	5.5	9.7	10.8	4.3	3.3	2.9	68.0
1958	18.9	5.1	8.6	10.3	4.1	3.2	2.4	67.8
1959	23.9	6.9	11.0	13.9	5.5	4.4	2.9	67.7
1960	26.6	8.0	12.1	16.2	6.5	5.3	2.9	67.9
1961	34.7	10.9	15.7	22.3	8.9	7.5	3.5	68.0

Table C.15. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, South Dakota, 1939 to 1961

Years	NPK Application per Acre Corn lbs.	Wheat lbs.	Oats lbs.	Barley lbs.	T. Hay lbs.	Flax lbs.	Percent of State Consumption
1939							
1940	.0[a]	.0[a]	.0[a]	.0[a]	.4	.0[a]	92.8
1941	.0[a]	.0[a]	.0[a]	.0[a]	.4	.0[a]	92.5
1942	.0[a]	.0[a]	.0[a]	.0[a]	.4	.0[a]	92.5
1943	.0[a]	.0[a]	.0[a]	.0[a]	.4	.0[a]	91.7
1944	.0[a]	.0[a]	.0[a]	.0[a]	.2	.0[a]	91.6
1945	.0[a]	.0[a]	.0[a]	.0[a]	.2	.0[a]	89.0
1946	.1	.0[a]	.0[a]	.0[a]	.9	.0[a]	89.8
1947	.2	.0[a]	.0[a]	.0[a]	1.8	.0[a]	88.7
1948	.4	.0[a]	.0[a]	.1	3.6	.1	90.7
1949	.3	.0[a]	.0[a]	.1	2.4	.1	90.8
1950	.2	.0[a]	.0[a]	.0[a]	1.4	.0[a]	90.2
1951	.5	.1	.2	.1	1.0	.1	85.7
1952	.7	.1	.3	.2	.6	.1	81.1
1953	1.2	.1	.6	.3	.5	.1	78.9
1954	2.5	.3	1.2	.6	.5	.2	76.4
1955	3.4	.7	1.4	.9	.6	.2	77.8
1956	3.1	.8	1.1	.8	.4	.1	78.7
1957	2.6	.9	.8	.7	.3	.0[a]	78.8
1958	3.9	1.4	1.0	1.0	.3	.0[a]	81.4
1959	4.6	1.7	1.0	1.2	.3		82.8
1960	4.2	1.7	.9	1.1	.2		83.6
1961	6.8	2.8	1.2	1.8	.3		84.7

[a]Less than .05 pounds per acre.

Table C.16. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Texas, 1939 to 1961

Years	Corn lbs.	Wheat lbs.	Oats lbs.	Cotton lbs.	T. Hay lbs.	G. Sorghum lbs.	Barley lbs.	Rice lbs.	Percent of State Consumption
	NPK Application per Acre								
1939	2.0			2.2				.7	75.7
1940	2.3			2.6				1.5	71.6
1941	2.7			3.1				2.3	67.6
1942	2.5			2.9				2.6	63.5
1943	3.4			4.1				4.1	59.4
1944	3.8			4.4				4.8	55.3
1945	3.8	.2	.3	4.4	5.0	.0[a]	.1	8.5	54.1
1946	4.5	.5	.6	5.0	10.7	.0[a]	.3	13.9	52.9
1947	4.1	.6	.7	4.6	13.6	.1	.3	15.7	51.5
1948	4.2	.8	.9	4.7	18.8	.1	.4	17.8	49.3
1949	3.8	.8	.9	4.2	19.5	.1	.4	18.0	47.9
1950	5.7	1.4	1.6	6.1	31.4	.1	.7	30.5	46.6
1951	8.3	.9	1.1	6.2	21.7	1.4	.5	33.4	52.6
1952	13.2	.8	.8	7.9	16.8	3.0	.4	45.3	58.7
1953	18.5	.6	.5	9.8	11.1	4.9	.3	58.5	64.6
1954	22.1	.3	.2	10.7	4.0	6.3	.1	65.7	70.4
1955	22.3	2.3	1.7	13.0	4.3	7.3	1.0	73.4	69.0
1956	23.5	4.7	3.4	16.2	4.6	9.0	2.1	83.6	68.9
1957	23.2	6.9	5.1	18.5	4.5	10.2	3.1	88.7	69.0
1958	23.4	10.2	6.8	22.3	4.8	12.6	4.3	96.3	70.1
1959	21.2	11.2	7.7	22.2	4.4	12.4	4.8	93.2	69.1
1960	21.2	13.8	9.3	25.1	4.5	14.0	5.9	99.9	68.9
1961	21.2	16.6	11.0	28.2	5.2	15.8	7.1	107.0	68.3

[a]Less than .05 pounds per acre.

Table C.17. Estimated application rates of primary plant nutrients in pounds per acre by crops and percentage of total state consumption, Wisconsin, 1939 to 1961

Years	Corn lbs.	Wheat lbs.	Oats lbs.	Soybeans lbs.	T. Hay lbs.	Potatoes lbs.	Percent of State Consumption
	NPK Application per Acre						
1939	5.3	1.6	2.0		.2	20.6	96.1
1940	8.0	3.2	4.0		.2	35.0	95.1
1941	10.3	4.7	5.8		.8	51.0	94.2
1942	21.0	10.4	12.9		2.0	113.8	93.2
1943	13.9	7.8	9.7		1.6	76.2	92.3
1944	15.3	8.3	10.2		1.8	89.9	91.3
1945	18.1	10.6	13.3	1.2	1.8	92.2	90.3
1946	22.3	14.5	18.3	2.6	2.2	97.1	89.4
1947	26.5	18.4	23.4	4.0	2.5	99.4	88.5
1948	32.4	23.5	29.9	5.9	2.9	108.3	87.5
1949	30.9	23.3	29.5	6.5	2.5	97.4	86.6
1950	31.2	24.4	30.5	7.3	2.4	87.3	85.7
1951	40.9	29.0	31.7	16.8	2.9	139.3	85.5
1952	44.5	28.9	27.9	23.2	2.9	165.3	85.3
1953	49.7	30.2	25.7	30.0	3.1	199.8	85.0
1954	57.8	33.3	25.1	38.6	3.4	244.3	84.9
1955	59.2	35.0	25.7	32.8	4.1	268.0	85.6
1956	60.3	36.4	26.2	27.2	4.8	289.0	86.3
1957	65.9	40.5	28.5	23.7	5.9	332.2	87.0
1958	70.1	43.7	30.0	19.2	6.8	370.4	87.6
1959	74.9	48.2	32.5	15.2	7.9	412.1	88.3
1960	70.2	45.6	30.6	9.4	7.9	397.8	89.0
1961	79.5	52.1	34.0	5.5	9.3	466.4	89.7

XIII. APPENDIX D

Table D.1. Annual barley weather indices by states[a]

	Barley Weather Indices					
Year	Minnesota **	Montana n	Nebraska **	N. Dakota -	S. Dakota **	Wisconsin n
1940		.54	.44			
1941		1.22	1.10			
1942		1.06	.87			
1943	.87	1.25	1.05	.81	.57	.69
1944	.62	1.31	.71	.76	..59	.72
1945	1.16	1.12	1.00	1.30	1.66	1.15
1946	1.16	1.10	1.73	.88	1.18	.76
1947	1.09	1.07	1.57	.99	.83	1.36
1948	1.05	1.09	1.17	1.17	1.15	1.08
1949	.85	.83	1.19	.86	1.04	1.01
1950	1.17	1.27	.70	.95	1.14	1.14
1951	1.11	.92	1.01	1.31	1.14	.53
1952	.68	.78	.64	1.02	1.04	.68
1953	.89	.87	.50	.98	.76	.95
1954	.94	.96	1.10	.82	.99	.85
1955	1.06	1.08	1.01	1.25	1.25	.95
1956	1.04	.82	.46	1.22	.62	.87
1957	1.08	.89	1.10	.79	1.24	1.04
1958	1.12	1.70	1.29	.92	.97	1.66
1959	.89	.93	1.18	.96	.29	1.15
1960	.89	.71	1.49	.93	1.37	1.03
1961	1.16		1.26	1.11	1.11	1.08

[a]Source: References; Barley.

**Index tested statistically significant at the one percent level in production function analysis.

-Index did not test statistically significant at the ten percent level in production function analysis.

[n]Index was not tested statistically in production function analysis.

Wherever applicable identical notations used in Tables D.2 to D.9.

Table D.2. Annual corn weather indices by states[a]

Years	Arkansas	Illinois	Indiana	Iowa	Kansas	Michigan
	**	**	**	**	**	**
1926				1.14		
1927				.98		
1928				1.15		
1929				1.25		
1930				.97		
1931				.91		
1932				1.28		
1933				1.06		
1934		.75		.89		
1935		1.29		.99		
1936		.67		.56		
1937		1.25	1.21	1.05		
1938		1.09	.92	1.03		1.08
1939		1.23	1.13	1.08	1.22	1.21
1940		1.10	.79	.98	.73	1.04
1941		1.06	1.07	.91	.89	1.08
1942	1.43	1.07	1.16	1.07	1.18	.95
1943	.97	1.02	1.03	1.07	1.03	.93
1944	.79	1.00	.94	.97	.99	.98
1945	.95	.89	.93	.89	.92	1.11
1946	.86	1.07	1.16	1.08	.89	.78
1947	.83	.68	.75	.66	.89	.62
1948	1.14	1.03	1.20	1.05	1.41	.96
1949	1.26	.86	.97	.90	1.52	.98
1950	1.53	.79	.62	.86	1.43	.93
1951	1.42	.92	.98	.80	1.04	.96
1952	.37	1.09	.94	1.08	.80	1.07
1953	.66	.98	.86	1.05	.53	1.08
1954	.34	.96	1.13	1.05	.50	1.17
1955	1.31	.97	.94	.91	.67	.99
1956	1.03	1.24	1.06	1.00	.68	.94
1957	.89	1.05	1.10	1.06	.90	.96
1958	1.08	1.06	.90	1.11	1.22	1.16
1959	1.08	1.00	.98	1.09	1.37	1.05
1960	1.20	.94	1.13	1.04	.92	.86
1961	.97	1.05	1.11	1.11	1.30	1.05

[a]Source: References; Corn.

Table D.2 (Continued)

Year	Corn Weather Indices Minnesota **	Mississippi **	Missouri **	Nebraska **	North Dakota **
1937	1.03		1.07	1.04	
1938	1.08		1.09	1.02	
1939	1.39	.78	.99	.74	
1940	.96	1.18	.99	.96	
1941	1.11	1.04	.96	.78	
1942	1.06	1.10	.99	1.16	
1943	.95	.82	1.07	.83	
1944	1.15	.72	.97	1.46	1.27
1945	1.05	1.28	.89	1.03	.98
1946	.93	1.21	1.08	1.01	1.00
1947	.69	.83	.76	.66	1.00
1948	.91	1.02	1.16	1.37	1.08
1949	.85	1.22	1.04	1.05	1.04
1950	.73	1.24	1.16	1.29	.91
1951	.76	1.10	1.13	.81	.74
1952	.94	.58	1.11	1.09	.81
1953	.90	.78	.82	1.05	.82
1954	.99	.82	.56	.86	.96
1955	1.04	1.01	.97	.53	1.02
1956	1.16	.84	.96	.54	1.22
1957	1.14	1.06	.91	1.00	1.16
1958	1.12	1.04	1.13	1.25	.95
1959	1.06	.94	1.04	1.13	.92
1960	.99	.88	1.06	1.18	1.08
1961	1.07	1.35	1.12	1.01	1.04
	Ohio **	Oklahoma **	South Dakota **	Texas **	Wisconsin **
1937			1.38		1.02
1938			.61		1.07
1939	1.26		.84		1.19
1940	.98		1.00		1.09
1941	1.08		.89	1.21	1.18
1942	1.25		1.25	.82	.97
1943	1.04	.30	.83	1.13	1.08
1944	.78	1.30	1.26	.87	.91
1945	1.00	1.09	.98	.87	.80
1946	.83	1.24	1.04	.93	.87
1947	.78	1.41	.76	1.02	.88
1948	1.12	1.46	1.32	1.04	1.01

Table D.2 (Continued)

Year	Corn Weather Indices				
	Ohio **	Oklahoma **	South Dakota **	Texas **	Wisconsin **
1949	1.05	1.30	.70	1.35	1.16
1950	.98	1.18	.95	1.23	.81
1951	.88	1.28	.86	1.03	.79
1952	.88	.47	1.07	.86	.98
1953	.79	.47	1.41	.66	1.00
1954	.84	.24	1.29	.73	1.17
1955	1.06	.64	.81	1.37	.99
1956	.97	0.00	.96	.74	1.07
1957	1.19	.70	1.19	.70	.90
1958	1.06	.99	.82	.99	.93
1959	.94	1.15	.48	1.15	.98
1960	1.13	1.22	1.08	.90	1.10
1961	1.12	1.56	1.30	1.25	1.12

Table D.3. Annual cotton weather indices by states[a]

Year	Arkansas **	Cotton Weather Indices Mississippi *	Oklahoma **	Texas *
1939		1.02	.99	
1940		1.01	1.31	.83
1941	.77	.89	1.22	1.36
1942	1.05	1.20	1.16	1.62
1943	.76	.97	.84	1.14
1944	.90	1.08	1.29	1.13
1945	.91	.96	.82	1.29
1946	.74	.77	.84	.59
1947	.90	1.03	.97	.82
1948	.98	.99	1.04	.71
1949	.91	.97	1.27	1.10
1950	.85	.98	.69	.92
1951	.76	1.06	.92	.54
1952	.76	.81	.67	.59
1953	1.33	.94	1.16	.63
1954	1.15	.82	.74	1.06
1955	1.52	1.20	1.31	.80
1956	.96	.84	.77	.79
1957	.87	1.16	.77	.77
1958	.93	1.05	1.28	1.01
1959	1.47	1.35	.82	1.23
1960	1.03	1.03	.87	2.06
1961			1.03	

[a]Source: References; Cotton.

*Index tested statistically significant at the five percent level in production function analysis.

Wherever applicable identical notation is used in Tables D.4 to D.9.

Table D.4. Annual flax weather indices by states[a]

Year	Flax Weather Indices Minnesota **	North Dakota -	South Dakota *
1939			1.02
1940			.90
1941			.99
1942			1.11
1943			.75
1944	.87	.89	.91
1945	1.28	1.36	1.05
1946	.96	1.11	.85
1947	1.19	1.19	1.35
1948	.95	.95	1.26
1949	.87	1.01	.79
1950	1.18	1.22	1.06
1951	1.03	.88	.74
1952	.85	1.10	.96
1953	1.02	.97	1.08
1954	.84	.90	1.12
1955	.98	.98	.75
1956	1.29	1.22	.85
1957	.69	.72	.86
1958	1.16	1.27	1.19
1959	1.16	.92	.75
1960	1.23	.74	1.34
1961	1.03	.49	

[a]Source: References; Flax.

Table D.5. Annual grain sorghum weather indices by states[a]

Year	Grain Sorghum Weather Indices Kansas **	Nebraska **	Oklahoma **	Texas *
1939	.13	.45		.95
1940	.38	.36		1.31
1941	1.06	.38		1.39
1942	.59	.56		.93
1943	.73	1.30		.61
1944	1.61	.78	1.10	1.31
1945	.86	1.12	.76	.35
1946	.72	.63	.86	.66
1947	.66	1.17	.57	1.21
1948	1.04	1.27	1.43	1.05
1949	1.27	1.75	1.30	1.80
1950	1.17	1.69	1.18	1.43
1951	.75	.54	.78	.85
1952	1.15	1.25	.93	.66
1953	1.06	.64	.97	1.27
1954	.39	1.08	.59	1.02
1955	.34	.18	.44	1.48
1956	.58	.72	.41	.60
1957	.92	1.26	1.08	.66
1958	1.48	1.36	1.80	1.38
1959	1.25	1.42	1.49	.84
1960	1.46	1.62	1.34	1.69
1961	0.00	1.04	0.00	0.00

[a]Source: References; Grain Sorghum.

Table D.6. Annual oats weather indices by states[a]

Year	Illinois **	Indiana -	Iowa **	Kansas -	Michigan **	Minnesota +	Missouri +
			Oats Weather Indices				
1942	.82	.77	1.02	.83	1.10	.97	1.03
1943	.76	.76	.90	.80	.51	.86	.58
1944	.55	.86	.97	.96	1.14	.94	.55
1945	1.29	1.10	1.20	1.18	1.33	1.22	1.29
1946	1.16	1.04	1.14	1.16	1.31	1.18	1.47
1947	1.11	.41	.97	2.01	1.14	1.17	.97
1948	.82	1.12	1.01	.97	1.26	.88	1.03
1949	.95	.44	.80	.97	.77	.94	.93
1950	.69	1.14	.98	.26	.93	1.06	1.14
1951	1.06	1.12	.88	1.08	.94	1.18	1.16
1952	1.02	.80	.88	.62	1.03	1.01	.79
1953	.68	1.12	.69	.79	1.09	.67	.78
1954	.85	.87	.89	1.44	.77	1.12	.84
1955	1.10	1.09	1.33	1.51	1.02	.95	1.41
1956	1.43	1.31	.82	.33	1.11	1.12	1.05
1957	.90	.96	.96	1.16	.86	.38	1.11
1958	1.64	1.51	1.34	.42	1.18	1.28	1.18
1959	.94	.98	1.08	1.06	1.04	1.16	.70
1960	1.12	1.12	1.37	1.09	1.03	.96	.85

Year	Nebraska **	N. Dakota *	Ohio -	Oklahoma **	S.Dakota **	Texas *	Wisconsin -
1942	1.21	1.26	.98	1.11		.95	1.32
1943	.93	.97	1.14	.71		.80	.80
1944	.55	1.40	1.23	1.21	.75	1.18	1.30
1945	1.14	1.32	1.27	.94	1.04	.94	1.33
1946	.81	1.01	.98	1.44	.91	1.44	.73
1947	1.21	.91	.89	1.31	.91	.89	1.46

[a]Source: References; Oats.

+Index tested statistically significant at the ten percent level in production function analysis.

Wherever applicable, identical notation is used in Tables D.7 to D.9.

Table D.6 (Continued)

	Oats Weather Indices						
Year	Nebraska **	N. Dakota *	Ohio -	Oklahoma **	S. Dakota **	Texas *	Wisconsin -
1948	1.30	1.37	1.04	1.17	.98	1.11	1.09
1949	.88	.73	.76	1.08	.78	.76	.59
1950	.94	.86	.80	1.06	.97	.96	1.04
1951	1.09	1.24	1.06	.82	1.23	.76	.88
1952	.90	.52	1.10	1.09	1.28	.91	.71
1953	.62	1.08	1.00	.85	1.07	1.65	1.09
1954	1.44	.85	.80	.92	.98	1.24	.76
1955	1.19	1.09	1.05	.60	1.25	.70	.94
1956	.72	.70	.63	.82	.59	.62	1.12
1957	1.03	.98	.88	.65	1.33	.55	.55
1958	1.41	1.28	.95	1.30	1.02	1.00	1.27
1959	.50	.75	1.10	1.02	.39	.94	1.09
1960	1.37	1.22	1.28	1.68	1.60	1.60	.90

Table D.7. Annual soybean weather indices by states[a]

Year	Arkansas	Soybean Weather Indices Illinois	Indiana	Iowa	Michigan
	-	*	-	**	-
1941		.99	.84	.51	
1942		1.22	1.02	1.17	1.17
1943	.54	.97	.92	1.00	.98
1944	1.58	.86	.98	1.12	.88
1945	1.44	.95	.97	1.01	.78
1946	.98	.90	.87	1.02	.74
1947	.59	.88	1.05	.80	.58
1948	1.00	1.08	1.08	1.18	1.17
1949	.73	1.02	.98	.91	1.50
1950	1.05	.95	.94	1.00	1.26
1951	.61	1.18	1.09	.98	.90
1952	.59	.89	1.13	1.14	1.00
1953	.81	.84	.99	.98	1.06
1954	1.28	1.07	1.05	1.08	1.20
1955	1.42	.70	.91	.80	1.11
1956	1.08	1.18	.92	.74	1.02
1957	1.80	1.23	1.08	1.10	.67
1958	.93	1.25	.90	.98	1.06
1959	1.15	.92	.94	1.17	1.04
1960	1.02	.96	1.07	.92	.80
	Minnesota	Mississippi	Missouri	Ohio	Wisconsin
	-	-	**	*	-
1941				.72	
1942	.91		.77	1.11	.91
1943	1.13	1.04	.92	1.16	.93
1944	1.17	1.29	1.06	.90	.99
1945	.80	.79	.78	.87	1.29
1946	.85	.81	1.17	1.02	.69
1947	.92	.77	.95	1.16	.92
1948	.94	.74	.95	1.10	.84
1949	1.12	1.03	1.04	1.14	1.08
1950	.84	1.63	1.31	.90	.90
1951	1.00	1.03	1.01	.57	.90

[a]Source: References; Soybeans.

Table D.7 (Continued)

Year	Minnesota	Soybean Weather Indices Mississippi	Missouri	Ohio	Wisconsin
	-	-	**	*	-
1952	.94	.83	.82	1.05	1.23
1953	1.06	1.11	.51	.73	1.20
1954	1.18	1.04	.31	.96	1.17
1955	.91	1.04	.84	1.19	.90
1956	1.18	.54	1.04	1.12	1.02
1957	1.20	1.11	1.36	.91	1.22
1958	1.04	1.20	1.48	1.25	.70
1959	.94	1.05	1.08	.80	1.04
1960	.82	1.24	1.34	1.26	1.11

Table D.8. Annual wheat weather indices by states[a]

Year	Wheat Weather Indices Georgia n	Illinois **	Indiana **	Iowa **	Kansas **	Michigan *
1927				.85		
1928			1.21	1.21		
1929		1.01		1.26		
1930		1.04		1.30		
1931		1.17		1.28	1.17	
1932		1.05		1.16	1.06	
1933		.84		1.13	.48	
1934		1.09		.63	.50	
1935		1.02		.99	.23	
1936		1.26		1.36	.57	
1937		.81		.91	.65	
1938		1.10		.71	.72	
1939		1.24	1.29	.85	.31	1.02
1940		1.29	1.00	.99	.45	.93
1941		.99	1.21	.50	1.06	1.15
1942	1.04	.44	.55	1.05	.89	.82
1943	.59	.80	.62	.90	1.12	.71
1944	.98	1.08	.87	.64	.98	.99
1945	.74	.90	1.19	.84	1.31	1.04
1946	.87	.67	.98	.96	.86	.92
1947	.70	1.02	.92	.84	1.41	1.11
1948	.78	1.16	1.10	1.24	1.50	.94
1949	.50	1.24	.97	.97	.51	.90
1950	.52	1.03	.77	.89	.90	1.06
1951	1.74	.73	.75	.66	.57	1.00
1952	.72	1.05	.78	.91	1.07	.73
1953	1.16	1.03	1.28	.91	.29	.98
1954	1.07	.94	1.02	.55	.40	1.17
1955	.88	1.06	1.10	1.33	.91	.87
1956	1.15	1.35	1.05	.98	.66	.97
1957	.90	.71	1.02	.94	.44	1.22
1958	1.44	1.31	1.47	1.44	1.21	1.50
1959	1.38	.64	.90	1.01	.79	.78
1960	1.40	1.23	1.28	1.25	1.24	1.29
1961				1.14		

Year	Minnesota **	Montana *	Nebraska Winter Wheat **	Nebraska Spring Wheat **	N. Dakota **	Ohio *
1929	1.24	.68	.92	1.22	1.10	
1930	1.34	.45	.92	1.44	1.22	
1931	1.25	.28	1.08	1.62	.82	
1932	1.18	1.36	.54	.63	1.41	

[a]Source: References; Wheat.

Table D.8 (Continued)

Year	Minnesota **	Montana -	Nebraska Winter Wheat **	Nebraska Spring Wheat **	N. Dakota **	Ohio -
	Wheat Weather Indices					
1933	.87	.80	.92	1.01	.60	
1934	.60	.48	.56	.28	.33	
1935	.93	.64	.76	.87	.87	
1936	.73	.11	.51	.56	.16	
1937	.92	.36	.16	.43	.76	
1938	.90	1.30	.57	1.03	.71	
1939	.65	.93	.59	.72	.80	.94
1940	1.39	.69	.29	.47	.56	.95
1941	.80	1.20	.36	1.04	1.02	1.32
1942	1.32	1.19	1.35	.56	1.51	.79
1943	1.03	1.48	1.06	.94	1.15	.86
1944	.86	1.44	.70	.40	1.29	1.02
1945	1.10	.72	1.68	1.16	1.11	.96
1946	1.10	1.07	.98	1.71	.96	1.09
1947	1.14	.77	1.13	1.57	1.17	1.05
1948	1.11	1.09	1.31	2.25	1.33	1.04
1949	.66	.92	.80	1.43	.70	.87
1950	.94	1.48	1.23	1.24	1.10	.92
1951	1.30	1.15	.72	.87	1.27	.82
1952	.61	.79	1.07	.85	.76	.85
1953	.80	1.02	1.03	.70	.81	1.32
1954	.53	.86	.56	.58	.52	.72
1955	1.06	1.04	1.35	1.35	.94	1.02
1956	1.24	1.04	.87	.87	1.06	.98
1957	1.04	.97	1.22	1.22	1.28	.96
1958	1.44	1.52	1.66	1.66	1.43	1.17
1959	1.26	1.17	.78	.78	.73	.12
1960	1.13	.82	1.15	1.15	1.25	1.19

Year	Oklahoma **	S. Dakota Winter Wheat *	S. Dakota Spring Wheat **	Texas -	W. Virginia n	Wisconsin +
1931	1.09	.59	.54	1.04		
1932	1.04	1.12	1.15	.52		
1933	1.04	.92	.81	.62		
1934	1.04	.21	.07	.74		
1935	.59	.72	.85	.25		
1936	.43	1.15	.38	.95		
1937	.82	.70	.36	1.38		
1938	.68	1.06	.65	.95		

Table D.8 (Continued)

Year	Oklahoma **	S. Dakota Winter Wheat *	S. Dakota Spring Wheat **	Texas -	W. Virginia n	Wisconsin +
		Wheat Weather Indices				
1939	1.27	1.44	1.08	1.11	1.09	
1940	.95	1.32	.92	.57	.99	
1941	1.16	.68	1.03	.63	.90	
1942	1.08	1.12	1.38	.58	.88	1.02
1943	.93	.75	.79	.95	.79	1.22
1944	1.50	.42	.76	1.22	1.17	1.03
1945	1.06	1.37	1.05	.75	.78	1.16
1946	.99	.69	1.47	1.03	1.05	1.04
1947	.96	1.09	1.28	1.22	.85	1.20
1948	1.07	1.26	1.30	1.09	1.23	1.32
1949	.92	.71	.96	1.09	.74	.80
1950	.48	.96	.94	.79	.93	1.08
1951	.52	.72	1.60	.48	1.32	.38
1952	.78	1.02	.73	1.07	.87	.92
1953	1.14	.96	.92	.95	.76	1.14
1954	.76	.56	.69	1.20	1.01	1.00
1955	.58	.76	.93	.91	1.13	.54
1956	.85	.13	.61	1.15	1.09	1.15
1957	1.13	1.32	1.17	.81	.70	.77
1958	1.18	1.76	1.43	1.19	1.29	1.59
1959	1.17	.80	.56	1.18	1.08	.83
1960	1.34	1.12	1.15	1.28	1.32	.98

Table D.9. Annual tame hay weather indices by states[a]

Year	Arkansas **	Illinois **	Indiana **	Iowa **	Kansas **	Louisiana **
1927	1.14	1.11	1.12	1.05	1.20	1.05
1928	1.09	.95	.97	1.02	1.20	1.03
1929	.93	1.04	1.00	1.05	1.09	1.02
1930	.68	.63	.63	.86	1.04	.79
1931	1.10	.89	.94	.72	1.07	1.02
1932	.81	.90	.87	1.08	.92	.93
1933	1.06	.83	.85	.91	.91	1.04
1934	.65	.56	.66	.42	.42	.93
1935	1.00	1.05	1.07	1.01	.63	1.04
1936	.62	.64	.66	.66	.61	.93
1937	1.03	1.01	1.06	1.00	.64	.95
1938	1.03	1.09	1.10	1.09	.97	1.04
1939	1.05	1.09	.99	.95	.88	1.03
1940	1.09	.94	.87	1.09	.95	1.01
1941	.99	.98	.83	.87	1.16	1.06
1942	1.12	1.14	1.13	1.16	1.24	1.08
1943	.76	1.00	1.04	1.11	1.02	.90
1944	1.03	.99	.86	1.19	1.22	1.00
1945	1.12	1.12	1.14	1.13	1.17	1.07
1946	1.08	1.14	1.08	1.13	.95	1.09
1947	.88	.97	1.09	.90	1.15	.95
1948	1.17	1.07	1.05	.92	1.18	.92
1949	1.14	1.10	1.10	1.05	1.23	1.10
1950	1.21	1.09	1.09	1.09	1.20	1.13
1951	1.01	1.16	1.09	1.21	1.26	.79
1952	.89	1.05	1.02	1.19	1.03	1.02
1953	.89	.89	.96	.95	.80	1.06
1954	.70	.94	.99	.96	.95	.89
1955	1.11	1.02	1.10	.85	.75	1.08
1956	.98	1.06	1.12	.83	.53	.89
1957	1.22	1.13	1.15	1.11	1.03	1.02
1958	1.20	1.15	1.17	1.09	1.26	1.11
1959	1.11	1.11	1.08	1.17	1.16	1.11
1960	1.07	1.14	1.12	1.18	1.18	.92

[a]Source: References; Miscellaneous, hay.

Table D.9 (Continued)

Year	Michigan **	Minnesota **	Mississippi **	Missouri **	Nebraska **	N. Dakota **
1927	.91	1.09	1.07	1.22	1.25	1.29
1928	1.06	1.06	1.06	1.05	1.03	1.11
1929	.87	.88	1.04	1.05	1.05	.80
1930	.70	.82	.77	.69	1.18	.89
1931	.76	.78	1.06	.99	.87	.72
1932	.97	.94	.94	.82	1.04	.93
1933	.84	.78	.98	.93	1.00	.78
1934	.59	.39	.92	.43	.37	.23
1935	1.07	1.08	.91	1.05	.96	.96
1936	.79	.78	.92	.52	.69	.48
1937	1.08	1.04	.99	1.01	.61	.72
1938	1.11	1.08	1.04	1.01	.89	.97
1939	1.00	.94	1.08	[illegible]	.74	.79
1940	1.13	1.03	.98	1.05	.71	1.16
1941	.93	1.05	.97	.86	.97	1.26
1942	1.15	1.18	.99	1.22	1.16	1.33
1943	1.11	1.11	.79	1.04	.95	1.20
1944	.94	1.10	1.06	1.10	1.19	1.26
1945	1.06	1.08	1.09	1.10	1.19	1.11
1946	.86	.94	1.14	1.17	1.01	.95
1947	1.01	.96	1.02	1.00	1.11	1.19
1948	1.00	1.04	1.04	1.17	1.03	1.23
1949	1.08	.98	1.14	1.20	1.26	1.05
1950	1.08	.95	1.12	1.20	1.18	1.13
1951	1.19	1.27	.77	1.20	1.29	1.16
1952	1.12	1.13	.87	1.05	1.17	.78
1953	1.09	1.13	1.04	.69	.99	1.18
1954	.96	1.07	.81	.77	1.10	1.15
1955	.96	.95	1.09	.97	.64	1.09
1956	1.18	1.08	.96	.88	.70	1.08
1957	1.09	1.14	1.09	1.06	1.16	1.19
1958	.92	.97	1.15	1.22	1.26	.88
1959	1.19	1.06	1.13	1.07	1.11	.80
1960	1.19	1.08	.97	1.10	1.16	1.13

Table D.9 (Continued)

Year	Ohio **	Oklahoma **	South Dakota **	Texas **	Wisconsin **
1927	1.15	1.19	1.28	1.08	1.00
1928	.92	1.14	.99	1.07	1.06
1929	1.08	1.02	.98	1.06	1.02
1930	.58	.86	1.02	.87	.82
1931	1.04	.97	.65	1.06	.70
1932	.77	.89	1.12	1.04	.85
1933	.89	.94	.83	.99	.85
1934	.73	.57	.16	.66	.55
1935	1.05	.82	1.00	.97	1.14
1936	.81	.54	.54	.92	.81
1937	1.09	.67	.75	.88	.86
1938	1.07	1.01	.89	1.07	1.17
1939	.91	.90	.67	.90	.92
1940	.92	1.05	.99	1.04	1.12
1941	.87	1.21	.99	1.34	.97
1942	1.13	1.21	1.33	1.22	1.20
1943	1.14	.87	1.04	.95	1.09
1944	.93	1.13	1.35	1.06	.98
1945	1.03	1.15	1.23	1.03	1.13
1946	1.07	.94	1.07	.97	.87
1947	1.13	1.11	1.12	1.08	.99
1948	1.07	1.17	1.21	.89	.87
1949	1.07	1.21	1.02	1.22	1.02
1950	1.06	1.25	1.17	1.19	1.03
1951	.94	1.12	1.33	.87	1.27
1952	1.00	.94	1.07	.81	1.22
1953	1.02	.95	1.22	.92	1.08
1954	1.01	.81	1.08	.81	1.03
1955	1.11	.91	.70	.92	.97
1956	1.12	.61	.97	.55	1.11
1957	1.01	1.10	1.26	1.06	1.08
1958	1.18	1.28	1.03	1.17	.89
1959	1.05	1.22	.78	1.19	1.18
1960	1.07	1.24	1.15	1.15	1.16